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Regional Power and Local Ecologies: Accumulated Population Trends & Human Impacts in the Northern Fertile Crescent.

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ABSTRACT

Archaeological data tends to be gathered at the local level: human agency also operates at this scale. By combining data from multiple surveys conducted within a larger area, it is possible to use local datasets to obtain a perspective on regional trends in settlement, population, and human activity. Here we employ data derived from nine archaeological surveys in the northern and western regions of the Fertile Crescent (west and north Syria, SE Turkey, and northern Iraq) to show how local trends aggregate to create a general proxy record of settlement and regional population. In addition, we use geoarchaeological data from a region extending from Homs in the west to northern Iraq in the east to outline historical trends in alluvial fill development. Both settlement and alluviation trends are then related to palaeoclimate proxy data from Soreq Cave and Lake Van. Settlement, geoarchaeological signatures and climate are then examined side by side in order to assess long-term human interactions.

Key Words: Fertile Crescent, local ecology, landscape archaeology, settlement archaeology, scale

1.0 Introduction

"Small-scale environments" or "ecological niches" are important research foci for the investigation of socioecological dynamics. However, a single region may include more than one such small-scale environment. In some cases, a given locality will consist of a patchwork of different physical landscapes, often deriving from a variegated geology, or differential access to water. In other cases, our environmental records relate to different scales of environmental influence. For example, the geoarchaeological sequences discussed here pertain to fluvial catchments of varying size, from major river basins to individual slopes. Consequently, the palaeoenvironmental record with which scholars must work may vary in scale from the highly local to the spatially extensive, the latter often reflecting a combination of processes in operation at multiple locations. Furthermore, the interference of humans with vegetation and hydrology can change significantly the nature of ecological niches, thereby presenting new opportunities for local communities. In such cases, human adaptation may not be a straightforward response to the local environment, but rather will take the form of human niche construction in which successful communities provide pathways for future development that deliver positive returns greater than would have been expected under the previous conditions (Kendal et al. 2011: 785).

Having sketched the significance of small-scale regional niches for the earlier phases of settlement for the northern Fertile Crescent (i.e. north Syria, southern Turkey and NW Iraq), we present a series of geoarchaeological case studies which are then related to long-term climate change and broader trends in settlement. For the latter, we employ a series of archaeological surveys (Fig. 1), which, when standardized, enable us to infer "settlement densities" for a range of sample areas across the northern Fertile Crescent. These not only provide a rough datum for assessing local human impacts on the landscape but also indicate local trajectories of settlement. We argue that while the micro-regions recognized continued

to be significant, after the Late Bronze Age (LBA) local ecologies frequently became overridden by the large scale imprint of the later territorial empires under the influence of which settlement trends became partly decoupled from the immediate environment.

The case studies comprise recent research from the Homs area (western Syria), the Orontes Valley, the Middle Euphrates, and from the Khabur Valley of eastern Syria. For brevity, the sequences from the areas reviewed are summarised, and references are made to more fully documented publications.

INSERT FIG 1

1.1 The role of local ecologies

Most ancient human settlement in the northern Fertile Crescent was supported by agricultural production, which in turn depended upon the quality and productivity of soils and the available moisture as derived from rainfall. Consequently, for an area like the Khabur basin soil maps demonstrate two basic patterns of soil. The first is a zonal development in which soils follow the rainfall gradients. The northern moister areas (with rainfall > 300 mm per annum) exhibit prismatic soil structure and carbonate nodules; further south, where rainfall is from 200-300 mm per annum, soils become shallower with progressively more gypsum as shallow desert soils predominate (Van Liere n.d.). Second, within any one zone different lithologies can result in very specific soils (intrazonal soils) which create local niches with markedly different physical and ecological properties than the local (zonal) soils (see below the two examples drawn from different areas of basaltic geology in eastern and western Syria). In addition to these variations in soil type, soil moisture can be time dependent. This is not only because of climatic cycles but also because the increased use of irrigation during the last 3000 years which radically changed the range of crop plants grown.

The significance of regional variations in ecology is also apparent in archaeological data. For example, recent palaeobotanical and isotopic research has demonstrated that climate proxy data from carbonized grain as well as variations in grain and associated faunal assemblages exhibit local or regional signatures (Riehl et al. 2014; Smith and Munro 2009). Consequently, Smith and Munro (2009) argue that soil moisture, itself a function of atmospheric humidity, produces different crop-faunal signatures which can be grouped according to local ecologies.

2.0 Regional Setting and Palaeoclimate

2.1 Physical Geography

The broad area under consideration forms a crescent-shaped configuration which receives sufficient rainfall for rain-fed cultivation, and which merges into the semi-desert to the south and the Zagros, Taurus, Amanus and Anti-Lebanon mountains, as well as the Jebel Zawiya forming an arc from east to west. The region can be subdivided into the following terrain types (Wilkinson et al. 2014), although it should be noted that these broad types encompass a much larger range of micro-environments (Fig. 2):

Agricultural Plains

These formed the “bread basket” of northern Mesopotamia because, although receiving only moderate rainfall, their large area compensated for yields that appear relatively low when compared to the irrigated landscapes of southern Mesopotamia (Weiss 1986). The rolling plains, which form a classic “landscape of tells”, underpin the “staple economy” of the numerous tell-based communities which grew up during the Chalcolithic and Bronze Ages. The valleys which dissect these plains show significant but varying degrees of alluviation

resulting in localized burial of settlements. The largest of these plains is centred on the upper Khabur basin (Fig. 2) where soils developed upon alluvial sediments washed from the mountains to the north as well as caps of Plio-Pleistocene basalts and outcrops of Pliocene sediments. Additional agricultural plains include the upland plains west of the Euphrates, specifically the Gazientep / Quoueiq plains; the Jabbul plain to the east of Aleppo; agricultural basins of the Harran/ Balikh and Saruj; the Amuq, Orontes and Ghab valleys together with the Marl landscapes south of Homs (Fig. 2).

INSERT FIG. 2

Alluvial valleys

The valleys of the Tigris, Euphrates, Orontes and Afrin Rivers and their tributaries provide well watered corridors and loci for long-term settlement. Eroded through Tertiary and Cretaceous limestone with occasional igneous rocks, these valleys have been infilled with deep alluvial sediments and are flanked by Pleistocene terraces (Demir et al. 2008). The fragmented landscapes through which they run provide smaller scale landscapes of tells with more muted settlement hierarchies than the extensive agricultural plains. However, where the valleys open up, or are flanked by broader plains, Bronze Age cities grew to some 50-60 ha in size. Because of their size however, and unlike the smaller valleys which drain individual units of agricultural lowland, geoarchaeological sections within the larger riverine basins respond to environmental influences integrated over large areas.

Uplands

In contrast to the agricultural plains, the uplands appear less densely settled, in part because of the types of building material used (mud-brick, wood and stone) which can result in a lower degree of site recognition, and in part because the agricultural carrying capacity, at least for some periods, was perceived of as low. However, during favoured periods, settlement developed over the uplands to create thriving communities that existed for centuries, but that also unwittingly contributed to landscape degradation. The uplands of western Syria and southern Turkey, which include limestone uplands and plateau basalts as well as the "sub-optimal" basalt lands west of Homs, are important to this investigation because the sedimentary record frequently derives from colluvial sequences which provide a sensitive record of local activities, rather than the more integrated (and regional) records derived from alluvial sequences (Dreibrodt et al 2014: 1351).

Intervening marginal lands:

Less distinctive geographically are the extensive semi-arid plains such as those extending between the Balikh and Khabur Rivers and around the Jebel Abd al-Aziz which seem to offer little potential for cultivation. However, such areas of potential grazing land were extensively settled by the occupants of numerous *kranzhügel* mounds and citadel cities during the third millennium BC (Smith et al. 2014). Similarly, the plains of central Syria to the east of Homs and Hama became the locus of settlement somewhat later during EB IV (Castel and Peltenburg 2007; Geyer et al. 2007; Maqdissi 2010). The above broad picture serves to obscure, or at least diminish, the significance of local variation. However, many areas exhibit marked variations in soil types and lithology which themselves create distinctive developments in local ecologies. Because these micro-regions supply variations in soil quality they probably contributed to the differential development of local economies. However, when researchers consider long term environmental influences on human settlement, such variations in the local soil resources have been rather neglected in favour of the ambient climate. Whereas much has been made of the role of climate change in the

demise of societies at, e.g. the so-called 8200 BP, 4200 BP and 3200 BP events, little has been made of variations of productivity that result from soils, whether this relates to their initial spatial patterning or from the loss of soil by erosion or nutrient depletion arising from 8000 years of land use.

The following examples demonstrate the distinctive variations in physical geography that exist at the local level, and which contribute to the development of small-scale ecological niches:

- The so-called *Chora* of Ebla (Fig. 3): basalt terrain; limestone uplands and plateaus; marshland and salt lakes; agricultural lowlands with *terra rossa* soils; as well as upland areas such as the Jebel Zawiyeh and Jebel al-Hass (Mantellini et al. 2013; Bitelli et al. 2013).
- Homs: Orontes Valley flood plain; marl plains; basalt terrain; etc. (Fig. 4a). Case study 4.1.
- Beydar (western Khabur basin): basalt plateau, alluvial valley floor, flood plain and low terraces; limestone interfluvies and slopes; (Fig. 4b)
- Amuq: A variegated landscapes of marshland, alluvial plains, alluvial fans, lacustrine basins; agricultural lowlands with surrounding igneous and limestone uplands, and high mountains became locally transformed by the growth of later marshes and lakes and increased erosion of the uplands. Case Study 4.2.
- Middle-Euphrates: upland plateaus; basalt plateaus; river terraces; alluvial flood plain, eroded limestone terrain. These all provide the context for a mixed farming economy with agriculture dominant on the lower terraces, pastoralism at higher elevations (and both in the uplands and lowlands of, for example, the Carchemish region). Case Study 4.3.
- The North Jazira of Iraq, probably the most homogenous region under consideration, consists of a flat plain lacking upstanding relief and with a remarkable uniformity of soil types. In contrast to the other areas where, for example, natural pastures appear to have developed upon specific geological niches such as basalts or limestone with associated shallow soils, the North Jazira appears to have seen the development of extensive pastures on lands that were previously settled. In other words, the local pasturelands were virtually created within the existing pattern of settlement, rather than being dependent on local natural ecologies. However, even here the pastoral reserves were developed on an area of very slightly raised upland which likely had lower moisture levels. On the other hand, similar terrain around Tell Brak in the central Khabur basin provides a dense pattern of settlement from the Neolithic on, dominated by Tell Brak. Case Study 4.4

INSERT FIG. 3

While many cultural landscape niches developed upon "natural" landscape units, some (e.g. pastoral enclaves in the North Jazira and marshes in the Amuq) appear to have been secondary developments. In the case of marshes in the Amuq Valley, and perhaps also in the Balikh, these appear to have developed as secondary features resulting from the undisciplined discharge of irrigation water during later periods (discussed below).

INSERT FIGS 4a & 4b.

2.2 Climate Proxy records

During the past twenty years the use of climate proxy measures derived from pollen, oxygen and carbon isotopes and tree rings have become increasingly important in the interpretation of patterns of human settlement. However, these records have usually been interpreted as cycles of wetter-drier or cooler-warmer phases. Conveniently, the northern Fertile Crescent is framed by two key records: the Lake Van record in eastern Anatolia to the north and the Soreq Cave sequence in the southern Levant (Lemcke and Sturm 1997; Wick et al. 2003; Bar Matthews and Ayalon 2004; Fig. 5). These proxy records suggest a moister early and mid-Holocene (until ca. 2000 BC) followed by a drier late Holocene. Nevertheless, the interpretations of such cycles can vary, with some researchers focussing on the late third millennium BC as the period of maximum aridity (Staubwasser, and Weiss 2006), whereas others, based on recent records from the Dead Sea and Sea of Galilee, argue for a peak aridity in the early 2nd millennium BC (MBI: Finkelstein and Langgut 2014). The latter then use regional patterns of settlement to posit a shift in population from more arid regions to "greener" parts of the Levant.

INSERT FIG 5.

It is generally accepted that the Holocene exhibited phases of aridity and increased moisture (Kucuoglu 2007), and the challenge now is to also establish spatial variability in palaeoclimate because this can be significant for local palaeoecology. For example, using isotopic analysis of cereal grains for a span of some 5,500 years of the Holocene, Riehl et al. recognize that "regional differences in climatic effects led to diversified strategies in ancient subsistence and economy even within spatially limited cultural units" (2014; 12348). Similarly, although again recognizing a series of climatic cycles, Haldon et al. show that during the millennium extending from the classical to the medieval worlds "Anatolia supports a substantial microregional differentiation in climate, land use and demographic history" (2014: 130-131; and fig. 2a). This perspective is also echoed in the Roman Mediterranean, where climate cycles are clearly recognizable, but appear to vary regionally (McCormick, et al. 2012). Unfortunately, the availability of palaeoclimatic proxy records is uneven across the Fertile Crescent. Anatolia and parts of the Levant are well represented, but Syria and Iraq provide little data, rendering it difficult to present a coherent record at a regional scale. Nevertheless, in the discussion that follows we recognize that regional patterns of climate, especially when taking the form of intense periods of deluges or floods, will play out in the micro-regional physical geography in a variety of ways and may have a significant impact on local geomorphological sequences. Moreover, the actions of humans to ameliorate local aridity can result in environmental patterns being reversed: a cautionary example derives from the northern Levant during the reign of Justinian, where the administration of Antioch in the moist north-west requested grain supplies from the climatically marginal region of Hieropolis / Membij (Casana 2003a). This flow of grain from a dry to a relatively moist area is now explained by the fact that the latter area was rendered productive by the extensive use of qanats and water conduits for irrigation (Lawrence and Ricci in press; Wilkinson and Rayne 2010).

3.0 Materials & Methods

Here we present:

- Geoarchaeological case studies from across the northern Fertile Crescent (Fig. 1), namely: The Homs region and Upper Orontes; the Amuq (Lower Orontes); the

Carchemish and Kurban Höyük regions (Middle Euphrates); the Jaghjagh river valley (Khabur basin of northeastern Syria). The case studies are based upon field descriptions, with supporting OSL, radiocarbon and artefact dating as available. Sedimentary descriptions are presented in referenced publications.

- Long-term population trends drawn from the Fragile Crescent Project database and presented in terms of a) individual survey areas; b) broad regions (i.e. western Syria; Mid-Euphrates and eastern Syria / northwest Iraq c) broad trends for the entire northern Fertile Crescent.

The long-term trends in settlement density presented here are derived from data modelled using the Fragile Crescent Project database at Durham University (Lawrence 2012, Lawrence, Bradbury and Dunford 2012). The database is designed to mitigate problems in making comparisons between surveys which use type-fossils, almost always ceramics and lithics, to ascribe individual sites to discrete chronological phases. Because changes in ceramic and lithic assemblages are not uniform across space or time, archaeologists must use different phasing schemes in different areas. Furthermore, these schemes may themselves change over time as more sites are excavated or assessed, scholarship progresses and particular type-fossils can be pinned down with greater accuracy. Thus the Late Chalcolithic (LC) period (4400-3000 BC in Northern Mesopotamia) has been treated as a single phase in some surveys (Eidem and Warburton 1997), sub-divided into five sub-phases in others (LC 1-5, Brustolon and Rova 2007), or organised in some combination of these, including into two (Wilkinson and Tucker 1995), three (Ur 2010) and four (Lawrence and Ricci, in press) phases. If we want to compare results from different phases both within and between surveys, some method for rendering them comparable is needed. The FCP database accomplishes this by assigning start and end dates to all phases and then displaying levels of settlement in relation to 'time blocks' of one hundred years each. The dates used were derived from a review of the literature and a range of recently published synthetic chronologies from across the region (Lebeau 2001, Cooper 2006, Porter 2007, Pfalzner 2010). One hundred year increments were chosen since this reflects the current level of precision available in the phase-based chronologies used. By transforming the individual phases into a similar metric we can model trends in settlement in a way that allows for direct visual comparison between evidence from different surveys (see, for example, Wilkinson et al. 2014, Bradbury, Braemer and Sala 2014, Lawrence and Wilkinson 2015). Importantly, this process is scalable, in the sense that by summing the level of settlement present in a number of surveys for any single time block we reach a real estimate of the same measure across the area of all the surveys at that time. We can therefore combine data from individual surveys to examine settlement trends in different environmental or geographical zones. This would simply not be possible within a conventional phase-based chronological framework due to the different lengths of the periods involved.

4.0 Results

4.1 Geoarchaeological Case Studies

Here we make a distinction between sedimentary sequences of large rivers, those of smaller rivers and those that simply relate to colluvial sequences. Colluvial fills are more pronounced around the upland fringes of the northern Fertile Crescent, and these, together with smaller alluvial catchments, tend to supply sedimentary records of local activity (resulting from both human action and local deluges). On the other hand the large alluvial catchments (especially the Euphrates, but also the Orontes) capture both environmental signals and human activities

integrated over larger regions. This makes comparisons between different sedimentary records difficult, but here we try to at least contextualize each record by supplying estimates of the catchment size of each basin discussed (Table 1).

4.2 The Upper Orontes

The project Settlement and Landscape Development in the Homs Region Syria surveyed an area of approximately 360km² area, located east of the Orontes River and south of the city of Homs. The landscape consists of Neogene lacustrine marl of late Miocene age, inter-bedded with the Late Miocene–Early Pliocene Homs basalt (Bridgland et al. 2012: 27). The landscape slopes gently downwards from the south-east towards the Orontes River in the north-west, and is cut by a number of shallow watercourses that flow with the direction of the gradient (see Philip et al. 2002, Fig. 6). Present-day agricultural practices have modified the landscape so that the meandering lower extents of these channels are often poorly defined, except by a gentle dip of slope and a thin deposit of flint and (occasionally) marl clasts along the former direction of flow. Fortunately the reflectance of these pebble trails is readily apparent on satellite imagery, Corona photography dating to the 1960s in particular. The pebble trails currently fade out several kilometres east of Lake Qatina, suggesting that water from these systems has not reached the lake in recent times, although hydrological reconstruction based on a Digital Elevation Model derived from SRTM data suggests that these may once have continued all the way to the Orontes.

At least some of these wadis appear to be fans, possibly caused by avulsion, originating from the Wadi ar-Rabi'a. The latter is a right-bank Orontes tributary that flows from south to north, draining a catchment of approximately 1500km² located on the eastern slopes of the Anti-Lebanon Mountains and an adjacent area of the steppe to the east, before bending around the northern flanks of the Anti-Lebanon to run in a deeply incised channel in a westerly direction towards the present-day town of Qusayr (Fig. 6a, Table 1). As the Wadi ar-Rabi'a is deeply incised, the north-west trending wadis described above now carry no more than surface run-off from small localised catchments. However, virtually all of the Bronze and Iron Age tell sites which are located east of the Orontes Valley proper are positioned along one or other of these wadi systems (Fig. 6b). This settlement system appears to have been relatively stable between the 4th/3rd and late 1st millennia BC (Philip and Bradbury forthcoming) suggesting that the wadis may have been of greater importance in hydrological terms in the past than their present-day appearance would suggest.

INSERT FIG. 6a, b, c

4.2.1 Landscape Reorganization in the Roman period

The Roman period, witnessed the abandonment of the majority of the tells and the appearance of a number of 'flat' sites which are interpreted as the remains of unfortified, agricultural settlements: when recorded on the Syrian or French maps these sites are usually associated with toponyms that include the term '*khirba*' (ruin) rather than '*tell*' (mound) (Philip and Bradbury forthcoming). While some of these were located along the same wadi systems as the earlier tell sites, others were not. A number of the flat sites were associated

with one or more areas of topographic depression. These features were frequently indicated on the Syrian 1:25,000 map series which were compiled in the 1980s from earlier aerial photographs, and are quite often associated with settlements of Roman or later date (Fig. 6c); the ceramic criteria used for dating are summarized by Reynolds (2014). We interpret these as deriving from the gradual collapse of clay-lined underground cisterns. A significant number of these depressions are not directly associated with the currently-visible watercourses. However, using the predictive hydrology model, a series of putative wadi courses could be extracted from the SRTM DEM (Fig. 6c). These appear to run in-between the present-day watercourses and show a much stronger association with the presence of depressions, suggesting that some of the cisterns were designed to be replenished from these smaller watercourses. This might indicate that the quantity of surface run-off in these systems was higher in the Roman period than in the Bronze or Iron Ages. An alternative hypothesis is that more efficient technology for the storage and management of water made it possible to locate settlements along watercourses that had not been viable with earlier technological options.

Depressions are also associated with sites producing a predominance of Byzantine and early Islamic period ceramics (the latter can be dated as late as the mid-10th century AD). While ceramic roof tiles occur regularly on sites of Roman-Byzantine date, they have also been recovered from some sites that produced mainly early Islamic material, suggesting that mudbrick buildings, utilising timber to support the weight of pitched, tiled roofs remained a feature of this landscape well after the Roman period (Philip and Bradbury forthcoming). This suggests that the settlement landscape that was first established during the Roman period remained in place for the best part of a millennium.

Another indicator of local hydrological management is supplied by the presence on Corona imagery of a canal (Fig. 7), running roughly south-north, a direction that differs from that of the tributary watercourses of the Orontes, which run from south-east to north-west. The channel appears to run around, and thus post-dates, the large Bronze Age settlement of SHR 14 (Tell es-Sefinat Nebi Noah); it appears, in fact, to have made use of the pre-existing ditch along the north-west side of the site. As the channel terminates at a Roman-Byzantine settlement (SHR 332) it can be interpreted as a Roman period construction. The course of the canal at its southerly (upstream) end can be traced on Corona imagery to within 3-400 m of the Orontes River, where even by the 1960s its traces had been erased by agricultural activity. However, it is probable that a small dam on the river, located a little under 4 km north (i.e. downstream) of the confluence of the Orontes and Wadi ar-Rabi'a, raised the water level sufficiently to provide a degree of gravity flow. The height of the channel drops less than 5 m along its entire course of just under 10 km. Between its source and site SHR 14, the course of the channel follows the contours very closely: the local topography militates against a straight route. Between SHR 14 and SHR 332 the channel shows strong meanders and a clear bifurcation. This lack of clear direction we attribute to the loss of energy entailed in navigating around SHR 14.

INSERT FIG. 7

4.2.2 *The Wadi ar-Rabi'a*

At the present time the course of Wadi ar-Rabi'a can be traced running to the south of Qusayr, after which it turns northwest and would appear to have joined the Orontes in the vicinity of the ancient water mill of Tahounet el-Qantara (indicated as TQ on Fig 6a). The Orontes has downcut since this confluence was last active and the former bed of the Wadi ar-Rabi'a is considerably higher than the present river channel. However, the Homs sheet of the French Levant Series of 1:50,000 topographic maps produced in the 1930s, and the 1964 Russian geological map (Homs-Trablus XIII XVIII 1964), indicate the channel as ceasing 0.65 km and 1.75 km east of the Orontes respectively. Examination of Ikonos imagery taken in spring 2002 suggests that the most westerly traces of anything resembling a wadi bed were by then located at least 2 km east of the Orontes. This evidence suggests that the wadi was not a significant contributor to the flow regime of the upper Orontes in the 20th century AD. This suggestion is reinforced by the fact that, despite a catchment area of some 1500km², the Wadi ar-Rabi'a receives no mention in Weulersse's (1940) account of the Orontes River, although other tributaries are discussed.

In fact, Weulersse (1940: 21, Fig. 8), notes that the upper reaches of the Orontes are largely fed by springs, as a result of which the annual flow cycle in the upper reaches of the river shows only modest seasonal variation, with peak flow falling in the months February through May and minimum flow in the months November through January. This flow cycle is quite different from that observed in the downstream sections of the Orontes where a winter maximum is the norm (Weulersse 1940: 38-39, Fig. 15). It is also out of step with the local precipitation regime. However, while Weulersse (1940: 35, Fig. 13), describes the catchment of the upper Orontes (i.e. that part located upstream from the dam at the northern end of the Lake Qatina) as being around 2500km² in extent, the addition of the Wadi ar-Rabi'a catchment would increase this to ca. 4000km². We therefore contend that when account is taken of the contribution of the Wadi ar-Rabi'a to the Orontes, it can be argued that both the absolute volume and the timing of peak flow would have been quite different from that which has been observed in the 20th century AD.

4.2.3 *Exposure of Section of Wadi ar-Rabi' a south of Qusayr*

Our understanding of the flow regimes in both the Orontes River and the smaller transverse wadi systems has been enhanced by the exposure of a cross-section of the infilled Wadi ar-Rabi'a in a recently-excavated gravel extraction pit immediately south of the town of al-Qusayr (Fig. 8). The section ran roughly north-south. The North end of the section was located at: 34.493539 degrees N / 36.570141 degrees E and the southern end at: 34.493887 degrees N / 36.570187 degrees E. Points were measured with a Leica GS20 dGPS using an EGNOS correction maintained for 60 minutes. The accuracy is c. 1m. The elevation at the northern point was 566.17m. The quarry exposes a series of tabular alluvial fan facies and palaeosols (Units 19-28 on Fig. 8) into which channels have been cut in two phases (Units 2-8 and 29-34). Optically stimulated luminescence (OSL) dates indicate a Pleistocene date (pre-50,000 BP) for the fan sedimentation (OSL 8 and 9 on Fig. 8, see Table 2 for details), while the trend from coarse (Units 19-21) to fine (Units 22-28) particles shows falling flow energy consequent of either a decreasing overall water volume or the flashiness of discharge. Such changes might be the result of climate change (a reduction in absolute rainfall or a change in the seasonality of precipitation) or tectonism (e.g. downcutting of the wadi channel in response to uplift). The three palaeosols (Units 23, 25 and 27) developed in the fine-grained alluvial sediments indicate periods of stability during which the fan surface would not have been subject to prolonged flooding. In contrast the conformable (except for the upper contacts

of the palaeosols) nature of the fan sequences suggests a mode of deposition that was unbroken by erosive episodes.

The two phases of channel development suggest a major change to the hydrological regime combining increased discharge with downcutting, while it is clear, based on the chronological data outlined below, that there is a considerable temporal hiatus from the earlier fan sedimentation. The first channel (Units 2-8, henceforth 'Channel 1') contains matrix and clast-supported, trough cross bedded gravels (Units 2-4) overlain by tabular gravels that are otherwise lithologically identical (Units 6-8). All the facies in Channel 1 are indicative of high-energy flow, which seems to have been focussed within multiple narrow channels initially, but which later spread to the entire channel area. Tile fragments were found at multiple points in the channel sequence suggesting that the deposits are of Roman date or later, while an OSL sample collect from a sand facies of Unit 8 (OSL 2 on Fig 8, see Table 2 for details) was dated to 1560 ± 340 BP (230 BC-AD 1130). The presence of fluvial gravels indicates a period of increased flow, perhaps in the form of a very flashy spring/winter discharge. This might explain why it was possible to make use of relatively minor wadis to fill cisterns during the Roman period, and thus may have contributed to changes in the regional settlement distribution. Channel 1 is cut by a second channel (Channel 2) that is filled with deposits that appear to have a rather different genesis from the former (Units 29-34). As was the case with Channel 1, the basal deposits in Channel 2 are trough bedded (Units 29-30), and are then succeeded by tabular strata (Units 31-34), suggesting as before that flow was initially in a series of small channels but later across the whole channel area. However, there is a significant difference in sediment calibre, as while Channel 1 was filled with gravels Channel 2 is filled by sands and muds. These data suggest a very different hydrological regime from Channel 1, i.e. that flow in Channel 2 was at a lower velocity than in Channel 1. Indeed, the presence of fine-grained beds (including a tabular clay - Unit 32) suggests the presence of standing water within the channel, which would either have resulted from higher base levels in the Orontes itself or a downstream blockage to the wadi. Channel 2 is dated by a single OSL measurement (OSL 7, see Table 2 for details) from the base of Unit 29 to 1330 ± 180 BP (AD 320-1140), i.e. the first millennium AD. These data suggest that the switch from high velocity discharge in Channel 1 to slower flow in Channel 2 occurred most probably in the second half of the first millennium AD. One possibility is that the low energy processes, indicative of still or slow moving water in Channel 2, might reflect the impact of the construction of the Qatina dam on the volume of water in Lake Qatina and thus on the absolute height of the surface of the resulting lake.

We therefore argue that the construction of cisterns to make best use of increased water flow, the creation of the Nebi Noah canal, and the construction of a large Roman period dam on Lake Qatina can, like the large-scale cadastration seen in the basaltic landscape to the west (Abdulkarim and Olesti-Vila 2007; Newson *et al.* 2008/09), all be best understood in terms of an attempt by the new Roman rulers to increase agricultural productivity through investment in major infrastructure. In light of all these developments we feel that Abdulkarim and Olesti-Vila (2007: 265) are probably correct to ascribe the construction of the dam at the north end Lake Qatina, the major expansion of Homs as an urban centre, and the cadastration discussed above, to a period between the late 1st and the end of 2nd centuries AD. These activities would constitute a logical development of the Roman annexation of the city and region in the latter part of the 1st century AD. In fact, it is possible that construction of a major dam at the north end of Lake Qatina (for discussion of the dam see Geyer and Calvet 1992; Kamash 2010) was intended to both make use of, and protect, the landscape around Homs (ancient *Emessa*) from destructive floods. When compared to the regime of the Upper Orontes in the 20th century

AD, the Late Antique channel would have witnessed periods of unpredictable high water volumes, generated by the contribution of surface run-off draining into the Wadi ar-Rabi'a.

To summarize the infrastructural investment that was undertaken in the first two centuries AD appears to have substantially reshaped both settlement organization and local agricultural possibilities – a process of anthropogenic niche construction. The success of these developments is demonstrated by the longevity of the associated settlement pattern, and by implication the associated constructions, which remained in place for many centuries after the end of Roman control in the area.

INSERT FIG 8

4.3 The Amuq and Ghab

The Amuq plain, which occupies the northern Orontes within the Turkish province of Hatay, exhibits a local ecology that is varied both spatially and temporally. The seemingly flat plain encompasses a mosaic of dried lake beds and marshes, alluvial fans and flood plains, enclosed by limestone and basalt hills to the north east, east and south overlooked by the majestic peaks of the Amanus Mountains to the west (Fig. 9, Casana and Wilkinson 2005). The presence of early Holocene marshlands played a key role in the development of major Chalcolithic centres such as Tell Kurdu (Özbal et al. 2004), whereas the broad fertile plains also allowed for a productive agrarian economy with the result that settlements such as Tells Kurdu and Tell 'Imar al-Sharqi had attained sizes of up to 10-15 ha during the fifth and fourth millennia BC. This culminated in the development of major centres such as Alalakh and Tayinat in the third, second and first millennium BC.

INSERT FIG 9

The Amuq illustrates how seemingly flat, basin-like plains do not simply accumulate sediment uniformly, but rather aggraded at markedly different rates, in the Amuq ranging from 0-1.75 m per thousand years depending upon local geomorphology (Wilkinson et al. 2001: table 1). In addition, long term trends in sedimentation vary through time depending upon the combined effects of regional climate and human activity.

Specifically, the extension of Hellenistic, Roman and Byzantine settlement into the uplands was associated with erosion of those areas and the complementary accumulation of colluvial fills, alluvial fans and valley floor alluviation (Casana and Wilkinson, 2005; Casana, 2008). This process was particularly evident within the immediate hinterland of the city of Antioch, which experienced the spread of a rash of minor settlements into erodible sandstone and shale uplands south east of the city, on to limestone uplands further to the east, and up to elevations of 1000 m above sea level in the Amanus Mountains (Fig. 9). In the Amanus Mountains this upper extension of settlement was probably associated with vine and olive husbandry which is still practiced up to similar elevations today. In the most vulnerable areas of sandstone and shale, Casana has demonstrated that massive aggradation resulted where settlement extended rapidly into what had previously been wooded uplands (Casana 2008). This erosion, which must have been exacerbated by local high intensity rainfall events, resulted in a burst of aggradation in the local valleys that ranged from 12–30 times the long-term mean for the region (Casana, 2008). Similarly, the encroachment of settlement into the nearby Amanus Mountains appears to have resulted in the rapid growth of alluvial fans in the neighbouring lowlands (Wilkinson 2003: fig. 7.10). An equivalent phase of aggradation is also evident in the vicinity of Kinet Höyük in Cilicia, where some 1.0–5.0 m of post-Hellenistic aggradation included 1.00 and 1.8 m of aggradation over successive re-buildings of Roman roads (Beach

and Luzadder-Beach, 2008). As in the Antioch region, rates of sediment aggradation peaked between the Hellenistic and Later Roman periods with accumulation rates being 2.5 times greater than both before or after this period (Beach and Luzzadder-Beach, 2008). A characteristic feature of the later phases of landscape use was the manipulation of the river systems for irrigation, specifically the Afrin which entered the plain from the east (Fig. 9). In addition to withdrawing water from the river, excess water from the downstream (outfall) ends of canals and irrigation systems contributed to the development of marshes and shallow lakes during the late first millennium BC and first millennium AD (Wilkinson, 1997; Casana, 2003b; Eger, 2011). This process of marsh and lake development is evident in the form of the accumulation of lacustrine deposits over archaeological sites and palaeosols of former fields (Wilkinson 2010: fi. 9.8; Yener et al. 2000: fig. 4). The main extent of the lake of Antioch is clearly post Late Bronze Age in date and, according to the Late Roman writers Libanius and Malalas, a lake was present in the early centuries AD; it then expanded further in early Islamic times to reach its maximum extent (Eger, 2011: fig. 3). Major canals of Hellenistic through Early Islamic date diverted flow from the Afrin River, and in the eastern plains were used to supply settlements and presumably their irrigation systems with water. Ceramics on the associated sites date the later phase of canal construction to the early Islamic period, the 7th and early 8th centuries AD, (Eger, 2011), at which time the lake and its reed-fringed marshes appear to have expanded eastwards. Although it is likely that no single factor contributed to the expansion of the Amuq Lake and its marshes, a combination of accelerated alluvial deposition, flooding, riverine avulsions, increased runoff from the surrounding uplands, and the outfall of excess irrigation water from canals contributed to the development and growth of the lakes and marshes (Wilkinson 1997; Casana, 2004; Eger, 2011; Gerritsen et al., 2008). Overall, these canals not only reduced the flow of the ancient Afrin River, but also discharged excess flow into marshes which therefore expanded accordingly. This transformed riverine lowland and intervening plains into a lacustrine and marshy plain of which only the fringes and eastern area could be regarded as dry cultivable land. As argued by Eger (2011) this transformation of the local ecology resulted in a significant degree of adaptation to the marshland environment by local communities. To the south within Syria, the Ghab Valley is a naturally marshy lowland which exhibited expanded marshes during the Hellenistic, Roman and Islamic Periods. Although local attempts were made to drain them during the Roman period, by the Islamic period expansion had again set in and, as in the Amuq to the north, the marshes expanded to include extensive areas of lake (Casana 2003a: 298–99; Eger 2011: 64). Overall, these two interconnected lowlands along the Orontes Valley, as well as showing varied local ecologies during the Holocene, saw these ecologies transformed by the development of periodic marshes. In contrast, in the late first millennium BC and first millennium AD, the surrounding limestone hills were densely settled by a mosaic of village communities and settlements and their fields, vineyards and olive orchards which contributed to soil erosion and the aggradation of valley fills (Casana 2003b).

4.4 The Middle Euphrates

The Middle Euphrates valley in southern Turkey and northern Syria is incised by the river to exhibit a long succession of terraces which span the entire Pleistocene and Holocene (Demir et al. 2008). Here we focus on the later sedimentary sequences from the valley in the Carchemish and Kurban Höyük areas (Fig. 1) which provide compelling evidence for a later phase of colluviation (Wilkinson 2010) and which followed on from earlier alluvial fills (Miller-Rosen and Goldberg in Algaze 1995; Pournelle in Algaze et al. 2001: 59). At the river basin scale, the complex alluvial fills of the Euphrates River have been interpreted as demonstrating the following chronological sequence:

- a pre-Holocene incised topography,
- a Late Pleistocene/Early Holocene episode of alluviation producing a so-called "high terrace" at +8-10,
- a forested and stable mid-Holocene landscape,
- a period of erosion and incision and valley floor settlement at the end of the 5th millennium BC,
- high floods in the third millennium BC,
- the accumulation of a +4m terrace in the second millennium BC,
- additional incision from the first millennium BC (Kuzucuoglu et al. 2004).

Because the large upstream basin of the river integrates environmental signals from both local and regional factors, it is difficult to recognize the cause of any specific event, although presumably regional climate was the main driver of alluviation at this scale.

However, when sedimentary sequences derive from smaller catchments (whether alluvial or colluvial) the signal of local activities strengthens. The following cases from the Carchemish and Kurban Höyük regions all relate to sequences from streams with catchments of ca. 150km² or less (Table 1). In the Carchemish region within Syria, tributary valleys became partly infilled with sedimentary accumulations that included post-Roman colluvia and thick deposits of high-energy alluvial deposits. Along the River Amarna, a 2.5 m thickness of alternating beds of colluvia and weakly developed paleosols overlay riverine channel gravels (c: Fig. 10a & 10b). The overlying colluvia indicate accelerated erosion of the neighbouring slopes during the Late Antique period (4th -7th century AD).

INSERT FIG. 10

In the Wadi Seraisat to the south, thick cobble and gravel beds of high-energy channel flow planed across and destroyed a pre-existing Roman–Byzantine industrial area (Fig. 10c). As in the Antioch region, this later phase of valley fill corresponded to a phase of post-Hellenistic settlement, when farmsteads and sprawling villages extended on to the uplands and hillslopes, thereby destabilizing soils and contributing to accelerated erosion, especially when exacerbated by high intensity rainfall events. In the Carchemish area, a long phase of nucleated tell-dominated settlement (from the Halaf to the LBA) was followed during the Iron Age by an initial phase of settlement dispersal away from tells (Fig. 11). By the Hellenistic-Roman, Late Roman and Late Antique periods, this dispersal on to the erodible limestone uplands was at its maximum extent, coinciding approximately with the period of the main colluvial and high-energy alluvial fills.

INSERT FIG. 11

In addition, the hydrology of the tributary wadis must have been influenced by the presence of numerous small open channels that abstracted water for irrigation and supplied drinking water for the Hellenistic, Roman and Late Antique settlements on the lower terraces and upper floodplain (Wilkinson et al. 2007). Further north, within the Kurban Höyük area in Turkey, landscape degradation was associated with the extension of settlement on to the riverine lowlands and upper terraces. The geomorphological manifestation of this degradation took the form of the rapid growth of alluvial fans on the main Euphrates terrace (Wilkinson 1990; 1999). Although these fans were apparently initiated at the beginning of the second millennium BC following a local settlement peak of Early Bronze Age date, arguably they

attained their maximum extent during the Late Roman and Byzantine phases when erosion had radically incised the chalky bedrock to form badlands and associated deep gullies (Fig. 12; Wilkinson, 1999; 2010). Similar patterns of soil erosion are associated with the Roman period even further upstream at the site of Arslantepe in the Malatya region (Dreibrodt et al. 2014). Throughout the Middle Euphrates region it seems that, alongside the broad scale trends in deposition associated with the Euphrates itself, we can discern local accelerated erosion and sedimentation in the smaller catchments.

INSERT FIG. 12

4.5 The Jaghjagh (Khabur Basin, Syria)

The alluvial sequences from the Jaghjagh provide a representative sample of the Upper Khabur Basin, where rolling plains are dominated by a dense network of tells and low mounds. Deriving its waters from springs nurtured below the Tur Abd Din hills to the north, the Jaghjagh basin extends some 1200-1600km² (Table 1) and had a mean annual flow between 1951 and 1975 of ca. 4.3 cu m sec, peaking at ca. 15 cu m sec (Deckers 2011: 85-86). However, as a result of over-extraction for modern irrigation the river was essentially dry during the summers by the 1990s and 2000s when the alluvial sequence was investigated. During the 5th and 4th millennia BC the channel fill of well-bedded sand and gravel containing micro-fossils indicates a fairly steady flow, with additional inflow from springs (Riehl 2011; Deckers and Riehl, 2007). Bed deposits were diachronous, with flowing water deposits being especially evident in the 5th and 4th millennium and continuing into the first millennium BC both to the north near Tell Hamidi (Deckers 2011: 88-92) and to the south at Tell Ma'az, Tell Barri and al-Amal (Figs. 13 a-c: GPS 23 & 24; GPS 12; and GPS 55). This lower alluvial sequence of "grey alluvium" is illustrated by a section at way-point TW055 (Fig. 13a). Unfortunately the OSL samples taken from this profile have proved problematic, and our dating of the sequence relies on the associated material culture. TW055 revealed a palaeosol or flood plain surface with a scatter of Bevel Rimmed Bowl sherds (dating to between 3600 and 3000 B.C.) a little above channel deposits implying a broader shallow channel, which contrasts with that of the later channel which was both deeper and wider (Wilkinson 2003: 104).

INSERT FIGS 13a-c

In contrast, the upper alluvium of brown, blocky, silty clays, which also infilled relict channels (Fig. 14), formed a deposit of sediment up to 2.5 m thick. Again, these were diachronous and date mainly from the first millennium BC and later (Fig. 13b GPS 23 & 24 containing a Late Assyrian kiln; Fig. 13b at TW055, with Iron Age and Late Antique sediments). Similarly at al-Amal the lower alluvial gravels were deposited in the range 6.4 to 2.9 k BP (Fig. 13c).

INSERT FIG. 14

Upstream and within other tributaries, OSL, thermoluminescence (TL) screening, and radiocarbon dating of sediments and carbonized material from the Wadis Jaghjagh, Khanzir and Jarrah provide age estimates on this upper clay fill in the region of 2600±400 BP (OSL), 2600±800 BP (TL screening), 2300±200 BP (OSL) and 2,200±900 (TL screening) (Deckers and Riehl, 2007). In addition, around AD 244 (1780 ± 30 BP), fragments of oak charcoal in clayey sand in the Wadi Jaghjagh (Deckers and Riehl, 2007) suggest that there was localized woodland destruction during the Roman/Parthian period. Despite the broad standard

deviations, the above dates for the upper fill support the artefactual and stratigraphic data from near Tell Brak for a later low-energy upper fill of Iron Age and later date. Together these later fills have helped create the present deep, narrow and meandering channel which contrasts with the more vigorous flowing shallow and probably less sinuous channel of the Chalcolithic - Iron Age.

These fills accumulated within a landscape exhibiting increasing settlement during the Neolithic, Halaf and earlier Chalcolithic, which attained a significant density by the fourth millennium BC (Wright et al 2006-7). Hints of this densely settled Late Chalcolithic landscape are also evident within the sedimentary fills in the floor of the Jaghjagh which included numerous exposures rich in LC and Uruk pottery. This episode of abundant settlement in a relatively verdant environment corresponds with the first cycle of urbanization in northern Mesopotamia (Ur 2010; Wilkinson et al. 2014). Whereas the number of settlements appears to remain fairly steady throughout the remaining millennia, settlement density attained a local peak during the Late Assyrian period, thereafter declining in the subsequent Hellenistic, Roman/Parthian, Sasanian and early Islamic periods. In other words, like the other surveys in the Khabur region, the area lacked the major post-Hellenistic growth in settlement evident in the Euphrates region and west.

A complicating factor is that an extensive network of shallow linear valleys (hollow ways: Wilkinson et al. 2010) radiate from the main tells in the region, extending the drainage net. Although the hydrological impact of these networks remains unclear, such an extension of the drainage network during at least the third and second millennia BC must have contributed to the delivery of both water and sediment to the main channels, thereby exacerbating flood peaks and sediment loads. In addition, the presence of canals that withdrew water from the Jaghjagh must have reduced flow for at least part of the year. The evidence for such canals derives from:

- a) remote sensing from CORONA spy photography and modern high resolution satellites which demonstrates the existence of several canals both to the north near Nisibis (modern Qamishli) but also at intervals along the Jaghjagh as far south as Tell Brak (Ur 2010b: maps 2 and 3: pre-modern irrigation). In addition, a canal trace on the surface leading to the Castellum at Tell Brak appears to have functioned during the Late Antique or more likely the Abbasid period (Ur 2011: 16).
- b) field checking of sections, which exposed canals in section or profile. Specifically, feature 027, ca. 2.3 km north of Tell Barri, was dated to ca. 2045 \pm 25 BP (subject to hard water effect) and probably functioned in the Parthian-Sasanian period.

Together such canals, which are estimated to date from the Neo-Assyrian period and later, like their counterparts in the Balikh Valley (Wilkinson 1998), probably reduced the base flows of the rivers significantly. Therefore any changes in fluvial discharge and associated sedimentary fills may not simply derive from climate alone.

In summary, the river discharge and associated alluvial fills are likely to have responded to both the broader patterns of climate change, and local responses to loss of woodland, changing sediment and water delivery from hollow ways, as well as discharge reductions from canals, especially during the last 3000 years.

4.6 Settlement and Demographic trends

In order to examine the role of human activity on geomorphological processes, we include estimates of long-term settlement from key survey areas throughout the region. The following

discussion examines settlement trends from nine surveys across Northern Mesopotamia over the last 8000 years at three different scales:

- individual surveys,
- in three groupings based on physical geography and spatial proximity,
- as a single combined total (Figs.14, 15 and 16).

From west to east, the three groups of surveys include those from the Orontes Valley (the Amuq and Homs (SHR) Southern Area), the Middle Euphrates Valley (the Kurban Höyük Survey (KHS), Titriş Survey (TS), Land of Carchemish Project (LCP) and Sweyhat Survey (SS)) and the Jazira Region (the North Jazira Survey (NJS), Tell Hamoukar Survey (THS), and Tell Beydar Survey (TBS)), which will be discussed in this order. References for each survey are supplied above or as appropriate. Such an approach enables us to examine trends in settlement at different scales and therefore to explore the tension between local and regional factors which may have been involved. We use settlement density, expressed as total settled area per km², to compensate for the different sizes of each survey and to take account of variations in site size through time which would not be visible in simple counts.

The two surveys from the Orontes Valley demonstrate similar trajectories over the period in question. After relatively low levels of settlement during the Neolithic and Early Chalcolithic, population increased at the beginning of the Late Chalcolithic (dated to 4500 BC in the Homs area (SHR) and 4400 BC in the Amuq), remained fairly stable until a decline in the Late Bronze Age, returned to earlier levels in the Iron Age and then increased dramatically during the Seleucid, Roman and Byzantine phases (Fig. 15a). The main differences between the surveys occur during the Levantine Early and Middle Bronze Ages (3400-1600 BC), when the Amuq appears to have been more densely settled, during a short period in the Roman-Byzantine and Early Islamic phase when both surveys experienced brief declines – during the 4th century AD for the Homs area (Reynolds 2014: 58) but slightly later in the Amuq, and after the Early Islamic phase, when settlement in the Homs area (SHR) continued before seemingly collapsing at the end of the 15th century AD. In the case of the Amuq, settlement returned to pre-Seleucid levels slightly earlier than in the Homs region. Some of these differences may reflect variations in survey strategy and chronological focus, as much as genuine differences in settlement history. The continuation in settlement visible in the SHR after the Early Islamic phase, for example, may be a result of the attention paid to this period by specialists on the project who were not available to the Amuq team, whilst the relatively low levels of settlement in recent times in both surveys is likely a result of the burial of these settlements under present-day villages. A notable feature of both survey areas is the absence of large nucleated settlements throughout the period in question. Even during the second urban revolution of the EBA, for example, when cities of up to 120 hectares emerged elsewhere in the region, the largest sites in the two surveys, Tell Nebi Mend (SHR) and Tell Tayinat (AVRP), did not exceed 20 hectares. This reflects a broader pattern in the Orontes Valley during this phase (see Wilkinson et al. 2014, Lawrence and Wilkinson 2015 for discussion). By the Classical period both surveys cover the hinterland of major urban centres (Homs/Emessa for the SHR and Antioch for the AVRP), and received significant landscape investment in the form of large scale irrigation and drainage projects as documented above for Homs and by Casana (2014) for the Lower Orontes Valley. The absence of the sorts of pulsating growth seen in urban centres helps to explain the broad stability of settlement in the two exemplar surveys, whilst the extraordinary expansion of occupied area during the later periods is indicative of a spread of small settlements out of the valley floors.

As in the Orontes Valley, the Middle Euphrates surveys display relatively similar settlement histories, although the magnitude of the changes involved is greatly increased (Fig. 15b). This

is partly due to differences in the size of the surveys, and particularly the small size of the Sweyhat Survey area (Wilkinson et al. 2004: 60km² compared to 500km² for the LCP and 400km² for the combined KHS and TS) which magnifies relatively small changes in total settled area. Thus the huge expansion in the Early Bronze Age in the SS is almost entirely the result of the emergence of the 40 hectare city of Tell es-Sweyhat. Both the LCP and KHS-TS included expansive urban centres of a similar size at this time, at Carchemish (44 hectares) and Titris Hoyuk (43 hectares) respectively, but this is not reflected in the data from these surveys to the same extent (Algaze et al. 1992). A similar phenomenon occurs in the Iron Age for the LCP, where the 100 hectare city of Carchemish accounts for the significant rise in settlement density, and the decline of the city to 40 hectares during the Seleucid phase results in a substantial drop in total settlement. Taking these urban site effects into account, the Middle Euphrates surveys demonstrate a fairly homogenous pattern, with rather lower Neolithic and Early Chalcolithic settlement increasing during the Late Chalcolithic before the urban boom and bust of the Later Early Bronze Age. After modest levels of occupation in the Middle and Late Bronze Age settlement expanded in all three surveys during the later territorial empires, especially during the Seleucid and Roman periods, before declines set in at different times after the Islamic conquest. Note that the drop in settlement in the Sweyhat Survey (SS) during the Early Byzantine phase (350-650 AD) is probably a result of the typology used; it is likely that many of the Roman and Early Islamic sites were also occupied during this phase, which clearly saw an expansion of settlement in the other two surveys.

INSERT FIG. 15

The problem of urban site effects in small survey areas is also evident in the Jazira region (Fig. 15c), particularly in the Tell Hamoukar Survey (THS) which covered 125km² and included the 100 hectare Early Bronze Age centre of Tell Hamoukar (Ur 2010). However, general patterns are still visible, with lower settlement densities in the Neolithic and Early Chalcolithic followed by an expansion in the Late Chalcolithic, continued dense settlement in the Bronze Age and fairly steady settlement levels throughout the Iron Age, Partho-Sasanian and Early Islamic periods. The massive decline between 400 and 600 BC is a result of our inability to recognise Achaemenid period ceramics in survey assemblages and the values presented almost certainly do not correspond to actual settlement levels. The sharp troughs in the North Jazira Survey (NJS) during the Late Bronze Age and Middle Iron Age are the result of similar ceramic recognition problems (Wilkinson and Tucker 1995). However, the trend of gradually increasing settlement density is still visible despite this, and it should be noted that if the same sorts of generalising chronological schemes as those used in the THS and TBS (Tell Beydar Survey) were applied to the NJS the peaks in the Middle and Late Assyrian periods would widen to cover these troughs. An interesting and genuine difference in settlement levels between the surveys occurs during the Khabur phase (equivalent to the Middle Bronze Age and early part of the Late Bronze Age in the other two regions), when declines in the THS and TBS correspond to a rise in settlement in the NJS. The large urban site in the NJS, Tell al-Hawa, is one of only a limited number of centres in the Jazira region to survive the transition from the Early Bronze Age to the Middle Bronze Age. A similar expansion of rural settlement around a continuing urban centres is visible at nearby Tell Leilan (Ristvet 2005, Arrivabeni 2010).

Combining the results from each group of surveys allows us to compare overall trends in settlement in the Orontes Valley, Middle Euphrates Valley and Jazira Region (Fig. 16). Common trends include low levels of settlement density prior to the Late Chalcolithic before a significant jump to a level which remained fairly consistent until the beginning of the Iron

Age, with a notable exception during the second half of the Early Bronze Age when the settlement trajectories briefly diverge. This is due to the differential impact of the second urban revolution (Akkermans and Schwarz 2003), most evident in the Middle Euphrates but also visible in the Jazira region. The absence of expansive urban sites in the Orontes Valley is reflected in the relatively flat line throughout this period. One of the most striking features of the graph is the disparity in *relative* settlement during the Late Chalcolithic and Early Bronze Age phases, with the Jazira far more densely occupied than the other two regions, followed by the Orontes Valley. The trend after this across the region could be read as settlement in the Orontes and Middle Euphrates Valley expanding to eliminate this gap, whilst the Jazira region remained at approximately the same level of settlement it reached during the Late Chalcolithic, notwithstanding several large fluctuations probably attributable to the ceramic uncertainties mentioned above. Settlement expanded during the Iron Age in the Middle Euphrates and remained steady in the Orontes Valley before a marked increase in the Seleucid phase which continued through the Classical period. A decline in settlement is visible in the Islamic phases in all three areas, although at slightly different times, beginning in the Middle Euphrates after the Early Islamic phase compared to after the Middle Islamic in the other two areas.

INSERT FIG. 16

The overall combined total graph incorporates all of the data from the nine surveys into a single settlement trajectory (Fig. 17). This included settlement counts per km² as a complement to the settled area density which allows the impact of changes in site size on the different trajectories to be assessed. Assuming site sizes to be the same, we should see a consistent gap between the two lines on the graph since the count will have a linear relationship with the total settled area. An increased gap would therefore mean an increase in site sizes whilst a decreased gap would suggest a decline in site sizes. The impact of the second urban revolution is clearly visible as a result of this way of displaying the data, with a rise in total settled area during the later Early Bronze Age which does not correspond to a rise in the count of occupied sites, meaning site areas must have increased. Similarly, the jump in settlement at the start of the Late Chalcolithic was in part related to increases in site size but also reflects a smaller increase in the number of occupations. The expansion visible in the Iron Age and Classical periods is similarly attributable to both an increase in site size and number of sites, with site size being more significant during the Iron Age and site counts more important from the Seleucid period onwards. Again, the absence of recent Islamic settlement is partly due to the survey methods employed and the burial of sites under modern villages. Excluding the Islamic phases, the total settlement graph shows only two periods of significant decline across the last 8000 years, one during the Late Bronze Age and one during Late Iron Age. Both of these are likely a result of problems relating to ceramic typologies, particularly our inability to recognise Achaemenid types during the Late Iron Age. Overall, however, the trend is one of relatively steady increase, with major jumps at the beginning of the Late Chalcolithic and Seleucid phases.

INSERT FIG. 17

5.0 Discussion

By examining data on settlement trends alongside climate proxy records it becomes evident that accelerated erosion resulting in relatively high-energy valley fills is more prevalent during the last two-three thousand years when climates were drier than during the third, fourth and fifth millennia BC. In the northwest Levant, parts of northern Syria and southern

Turkey, valley fills take the form of coarse deposits of colluvium or alluvium. This is in the region where, after around the 3rd century BC, settlement spread away from valleys on to the interfluvies and slopes, or increased in density within the valleys. Moreover, there was a significant increase in settlement (evident on Fig 15), in the western and Euphrates regions. Further east, specifically in the Khabur basin where such an increase in settlement during the last 2300 years is not evident, the record from valley fills includes a higher energy lower fill (indicative of perennial flow in the Jaghjagh) and a low-energy upper fill. However, the valley fills of large catchments tend to respond to broader basin-wide trends in hydrology and human activity, and these records should be interpreted accordingly. Overall, smaller colluvial basins in the west and north show stronger evidence for human-induced aggradation. Specifically for western Syria and in some smaller catchments, Hellenistic, Roman and Byzantine buildings and other structures have been recorded sealed below thick accumulations of colluvial, alluvial fan or alluvial deposits, especially in the Amuq Valley (Casana and Wilkinson, 2005), the Cilician coast (Beach and Luzzader-Beach, 2008), the Jebel al-Aqra near the Amuq (Casana, 2008), and in the Carchemish area (above). These episodes of aggradation appear to have been mainly restricted to the western and middle Euphrates regions. In contrast, the Wadi ar-Rabi'a in the Homs region shows renewal of wadi activity, both in terms of renewed channel cutting and accumulated fills, within roughly the last two millennia.

In the Khabur, where the Jaghjagh catchment was large and where settlement appears to have levelled off in the last 2000 years (following an Iron Age peak), the valley fills are associated with a significant change in both palaeohydrology and channel geometry. In other words, the later channel of the last 3000 years appears to have developed a narrower deeper channel, with a propensity to a meandering trace. In contrast the pre-Late Bronze Age channel flowed with greater vigour and was shallower and less sinuous. The evidence for a phase of accelerated erosion and aggradation in the west and north during the past two millennia is also evident in the Arslantepe area where local sequences demonstrate the significance of human-induced erosion and aggradation over the last 2000 years (Dreibrodt et al. 2014: 1365). Dreibrodt and colleagues consider that "whereas climate variability was the probable trigger of early Holocene erosion, mid-late Holocene geomorphological processes reflect responses to human impact on the landscape." In the case of the broader trends evident in the case studies discussed here, local settlement histories also appear to play a significant role in soil erosion and aggradation.

Moreover, as pointed out by Dreibrodt et al. (2014), climatic effects such as dry phases that weakened the vegetation cover would also have encouraged higher erosion. For the later phase of erosion the role of heavy rainfall events and deluges acting on an already destabilised land surface would have been particularly effective during the last 2000 or so years when more open land surfaces were being exposed by human activities (Casana 2008; Grove and Rackham 2001). However, current proxy records, although providing evidence of broadly wetter and drier trends, do not supply the critical evidence on the scale of individual rainfall events. It has also been argued that increased rainfall in the Syrian steppe drove the expansion of late Roman settlement into these more marginal areas. Such an expansion would result in increased high-energy deposits: geoarchaeological evidence may be provided by the Wadi ar-Rabi'a, as discussed above.

The above data lend support for the broader syntheses of Dusaar et al (2011), which demonstrate that during the later phases of history, human processes became more significant as a driver behind the accumulation of valley fills. Moreover, from the Byzantine period

onward soil properties played an increasingly important role, as the hillslope soil reservoir was progressively depleted during the late Holocene (Dusar et al. 2011: 137). Nevertheless, sedimentation rates do vary depending upon catchment size and valley position as demonstrated here and in the Sagalassos area (Dusar et al. 2012).

6.0 Conclusions

By combining data from archaeological surveys with geoarchaeological evidence it is possible to discern trends in the accumulation of valley fills, which can be interpreted through the lenses of both long-term climate change and more specific events, as well as that of changes in the size, structure and distribution of settlement. Local ecologies were significant to settlement development in many parts of the northern Fertile Crescent, despite the apparent uniformity of the terrain. However, the changes to settlement and agriculture that took place during the later territorial empires of the past three millennia, including irrigation and other aspects of hydrological management, the resulting development of secondary marshes in valley bottom locations, and the spread of settlement into upland zones that had previously been pasture, wooded steppe or perhaps waste, have in many areas transformed local ecologies considerably. Such developments were accentuated by deforestation of neighbouring uplands which reinforced the development of valley floor wetlands (Woodward et al. 2014). The result is that, during the first millennium BC and first millennium AD, depending on location, local ecologies were overridden by other types of evidence, including valley floor aggradation and the development of secondary marshes. The regional economies that contributed to these changes were associated with major increases in settlement and infrastructure but less so in the Khabur region. However, further east still, in the region of the huge Islamic cities of Samarra and Baghdad, similar pulses of settlement must have occurred, but these have not yet been investigated in terms of trends in valley fills. Although it appears that human-induced erosion and aggradation were more significant in the western Fertile Crescent, the size of the sedimentary catchments does have a significant influence on the sedimentary records.

The changes in settlement and agricultural practices visible in the archaeological and geomorphological records in west were a response to the economic opportunities offered by, and taxation demands of, later territorial empires. However, their specific manifestation varied according to the opportunities offered by each sub-region. For example: established agricultural zones such as the Homs marls and Amuq basin witnessed a modification and intensification of settlement (above), what had hitherto been lightly settled upland or ‘sub-optimal’ zones such as the Homs basalts and the Jebel Aqra underwent a very substantial increase in settlement (Casana 2008, 2014; Philip and Bradbury 2010), while the remarkable expansion of settlement into the arid regions east of Homs and Hama was underpinned by the construction of extensive hydrological management systems (Geyer 2009; Braemer et al. 2010). This is, in effect, a process of niche construction in light of local affordances and technical capabilities. As our dataset expands, and inter-regional comparison is facilitated, we can begin to discern the manner in which the impact of territorial states was experienced within different local contexts.

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Leverhulme Trust (Grant F00128/AR: The Vanishing Landscape of Syria), which supported analysis of the data from SHR. Thanks also go the Department of Archaeology at Durham University for sponsoring the Informatics Laboratory which was crucial for the analyses presented here. Thanks to Jason Ur for data on the Beydar and Hamoukar regions and to Jesse Casana for data on the Amuq Valley. The Optically stimulated luminescence dating of quartz from the Wadi ar-Rabi'a section was undertaken by Warren Thomson, at the Center for Nuclear Technologies, Technical University of Denmark, Risø Campus, Roskilde, under the guidance of Dr Andrew Murray, to whom we express our gratitude. The dating samples used in the interpretation of the Upper Khabur profiles were collected by Katleen Deckers and processed with the support of her project, sponsored by the Eliteförderung of the Landestiftung Baden-Württemberg. We thank Katleen for sharing these data, as well as providing extremely useful comments on later drafts of the paper, along with an anonymous reviewer. We also wish to thank the relevant departments of antiquities in Syria, Iraq and Turkey, and the directors of the named projects discussed in the text for providing the support for the original surveys. In Syria, the SHR and Land of Carchemish Projects benefitted significantly from permissions, help, and advice supplied by the Directorate of Antiquities and Museums in Damascus, Aleppo and Homs. We specifically wish to thank Dr Maamoun Abdulkarim, Director, Directorate General of Antiquities and Museums and Dr Michael al-Maqdissi, Director of Excavations, Directorate General of Antiquities and Museums, for graciously facilitating fieldwork in the areas of Homs and Carchemish. We are also grateful to Drs Nadim Fakesh, Sa'ir Yarta and Yusuf Kanjo and Mr Mohammed Ali in Aleppo, who gave their continued support to the Land of Carchemish Project, and to our Syrian collaborators Farid Jabbour, Maryam Bachich and their colleagues in the Homs office of the DGAM, for their active involvement in SHR. The Fragile Crescent Data used in this research is available from the authors. The core arguments of this paper reflect the vision of Tony J. Wilkinson, who passed away towards the end of 2014. We dedicate this article to him, as a remarkable scholar and friend.

Table 1: Estimated size of the catchments of the various basins mentioned in the text.

Name of Wadi system	Section	Catchment area (km²)
Zengin valley (J. al Aqra)	Casana 2008	31km ²
Avsuyu (J. al-Aqra)	Casana 2008	29km ²
Ilica Valley (J. al-Aqra)	Casana 2008	4.5km ²
Homs: Wadi ar-Rabi'a	Figure 8	1500km ²
Euphrates Carchemish- Birecik enclave (Kuzucuoğlu et al. 2004, 203).	Saraga Hoyuk	110,000km ²
Kurban Hoyuk	Badland catchment. Wilkinson 1990: fig. 1.6 p 20	30km ²
Nahr al-Amarna (Carchemish)	Fig. 9a	150km ²
Wadi Seraisat (Carchemish)	Fig. 9a	10km ²
Jaghjagh north of Brak		850km ²

Table 2. Summary of the burial depth, water content and total dose rate to quartz data, equivalent doses, and optically stimulated luminescence ages for samples from Wadi ar-Rabi'a section. Two of the quartz doses (OSL2 and OSL7) are well below the $2D_0$ suggested working range (Wintle and Murray, 2006) and are, therefore, considered reliable; but two of the quartz doses (OSL8 and OSL9) are at saturation. The age results for samples OSL8 and OSL9 indicate that they are either very old and can therefore only provide minimum ages, or they are incompletely bleached. Given their position within the depositional sequence, the former seems the most likely explanation

Sample No.	Depth (cm)	Water content (%)	Dose rate (Gy/ka)	D_e Quartz OSL (Gy)	n	OSL age (ka)
OSL 2 122450	200	5	1.77 ± 0.11	2.72 ± 0.56	20	1.54 ± 0.33
OSL 7 122451	600	5	1.86 ± 0.10	2.41 ± 0.28	23	1.30 ± 0.17
OSL 8 122452	580	5	1.16 ± 0.07	167 ± 10	2	144 ± 12
OSL 9 122453	500	5	1.17 ± 0.07	168 ± 11	2	143 ± 13

Figures

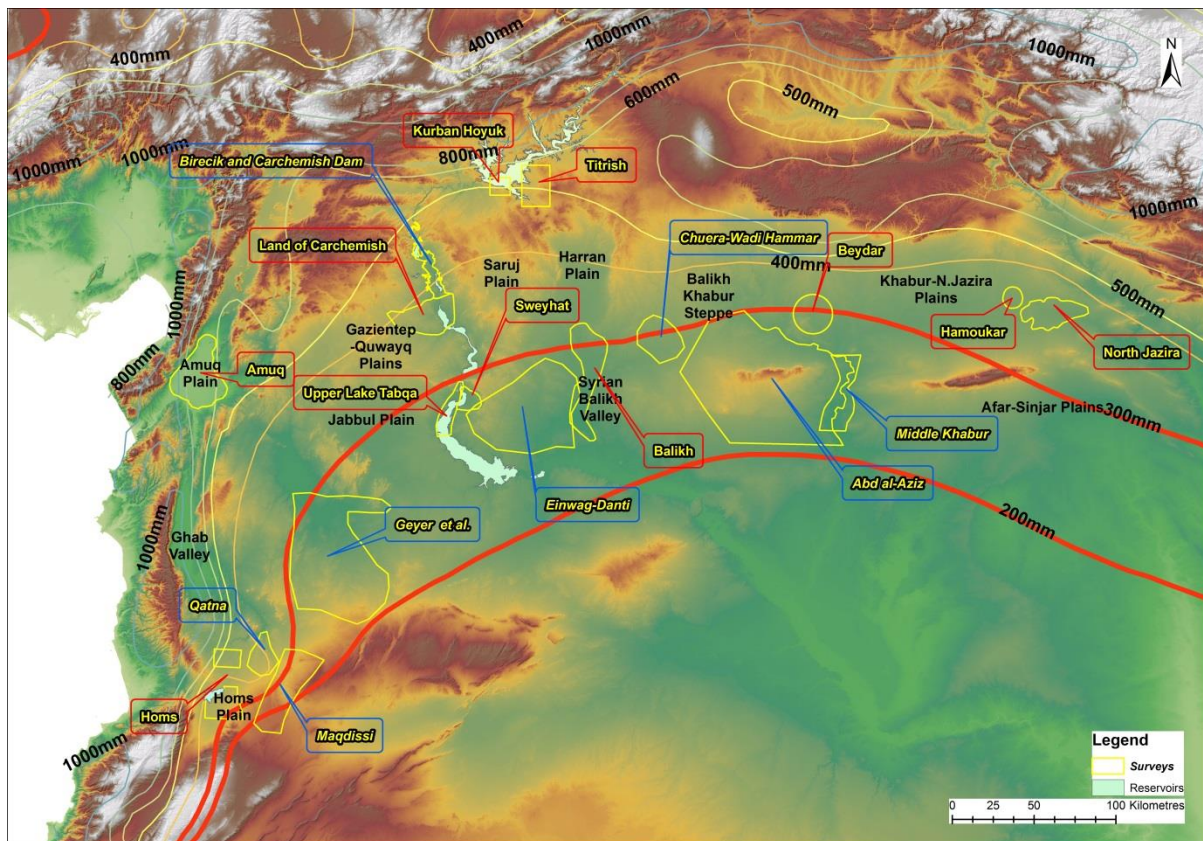


Fig. 1: The northern Fertile Crescent showing major archaeological surveys, including those discussed in the text, as well modern rainfall isohyets.

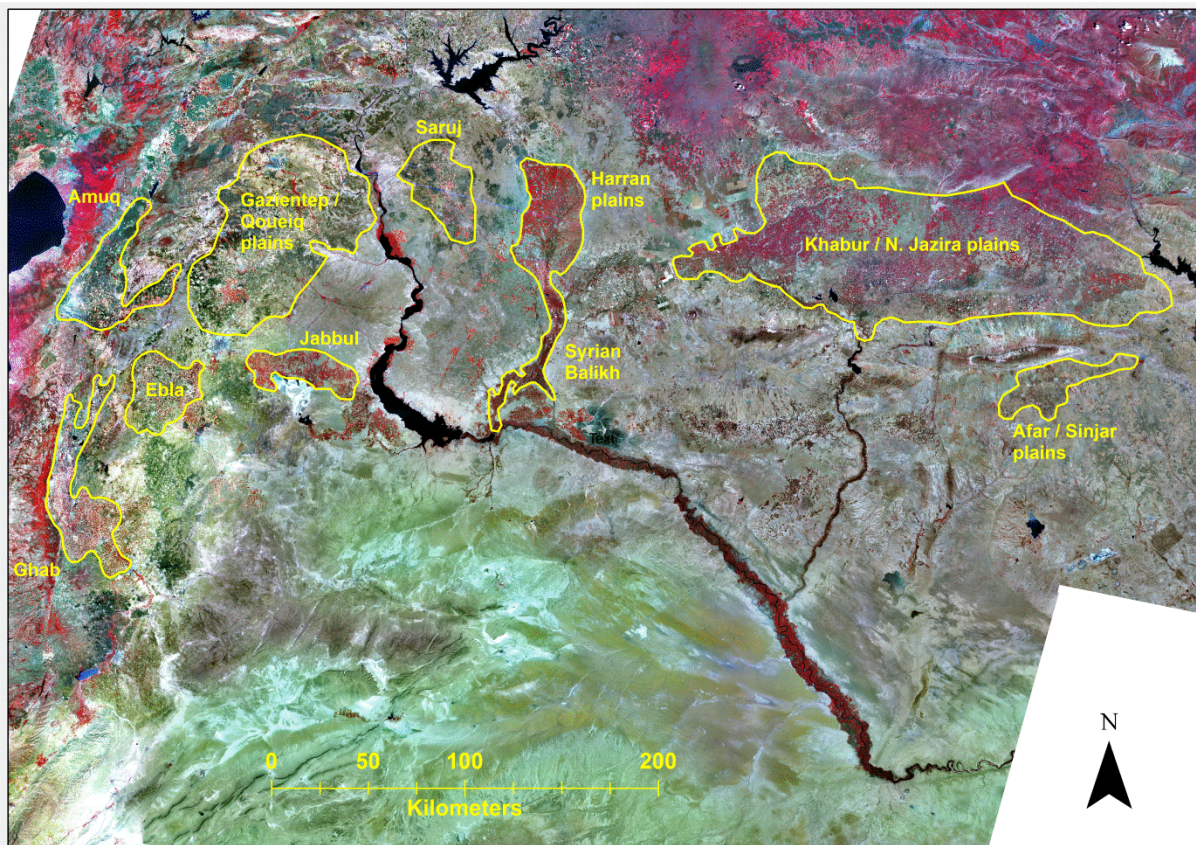


Fig. 2: Main agricultural regions of the northern Fertile Crescent superimposed on a composite LANDSAT Thematic Mapper false colour image using band combination 4,3,2.

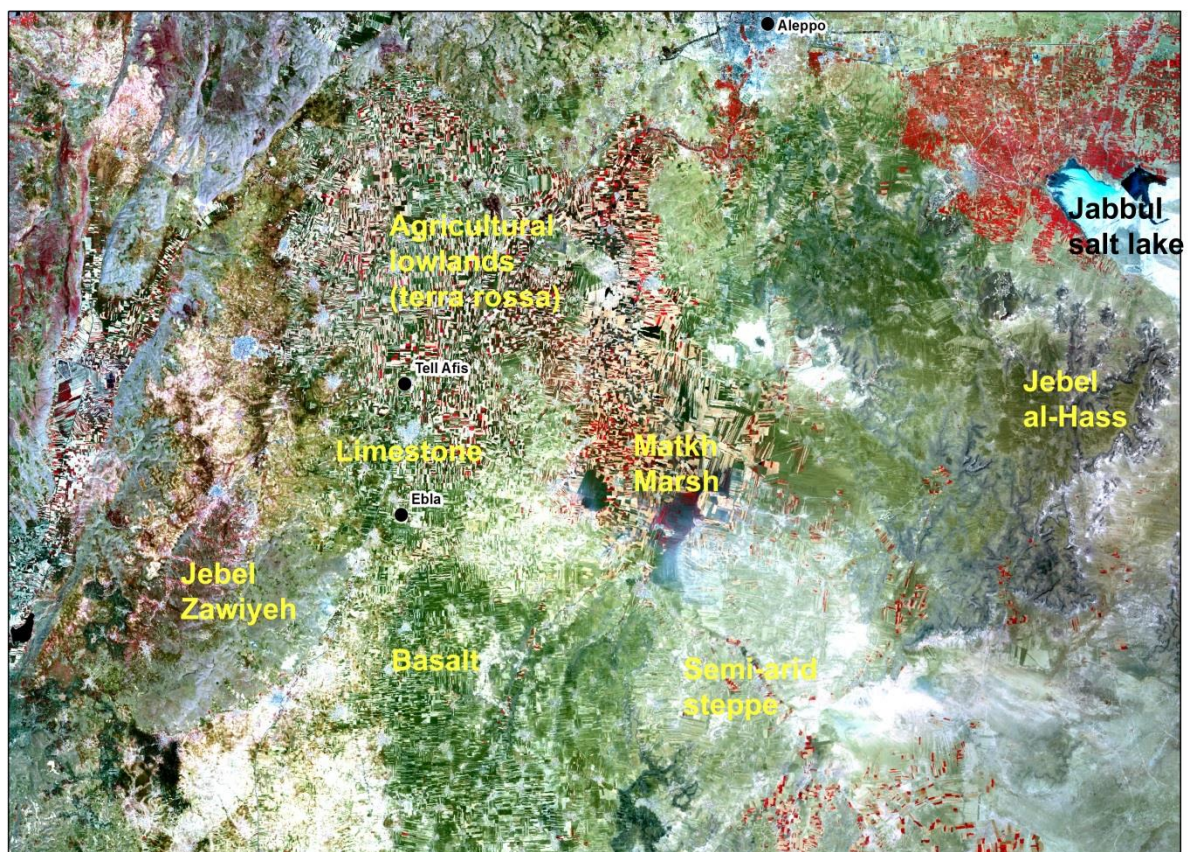


Fig. 3: LANDSAT Thematic Mapper false colour image using band combination 4,3,2, of the Ebla area showing the diversity of microenvironments evident and available for exploitation.



Fig. 4a. Homs (SHR Northern Study Area) region on Corona KH4B Mission 1108 acquired 17/12/1969, village of Sneissel in SW corner of image. Note the dense pattern of fields, which appear to date from the Roman period. (CORONA image courtesy of USGS).

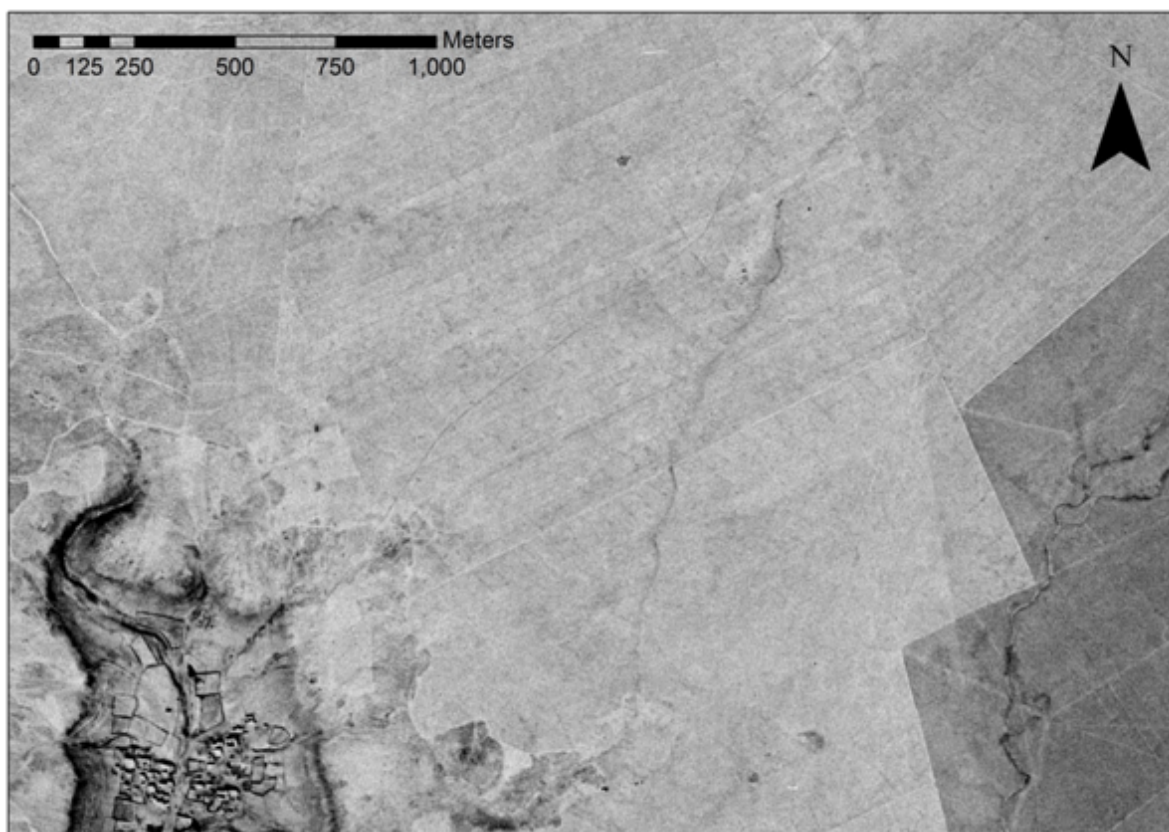


Fig. 4b. Hemma Plateau on Corona KH 4B Mission 1105 acquired 05/11/1968, village name unknown. Note the minimal records of archaeological features compared with the basalt plateau near Homs (Fig. 4a). (CORONA image courtesy of USGS).

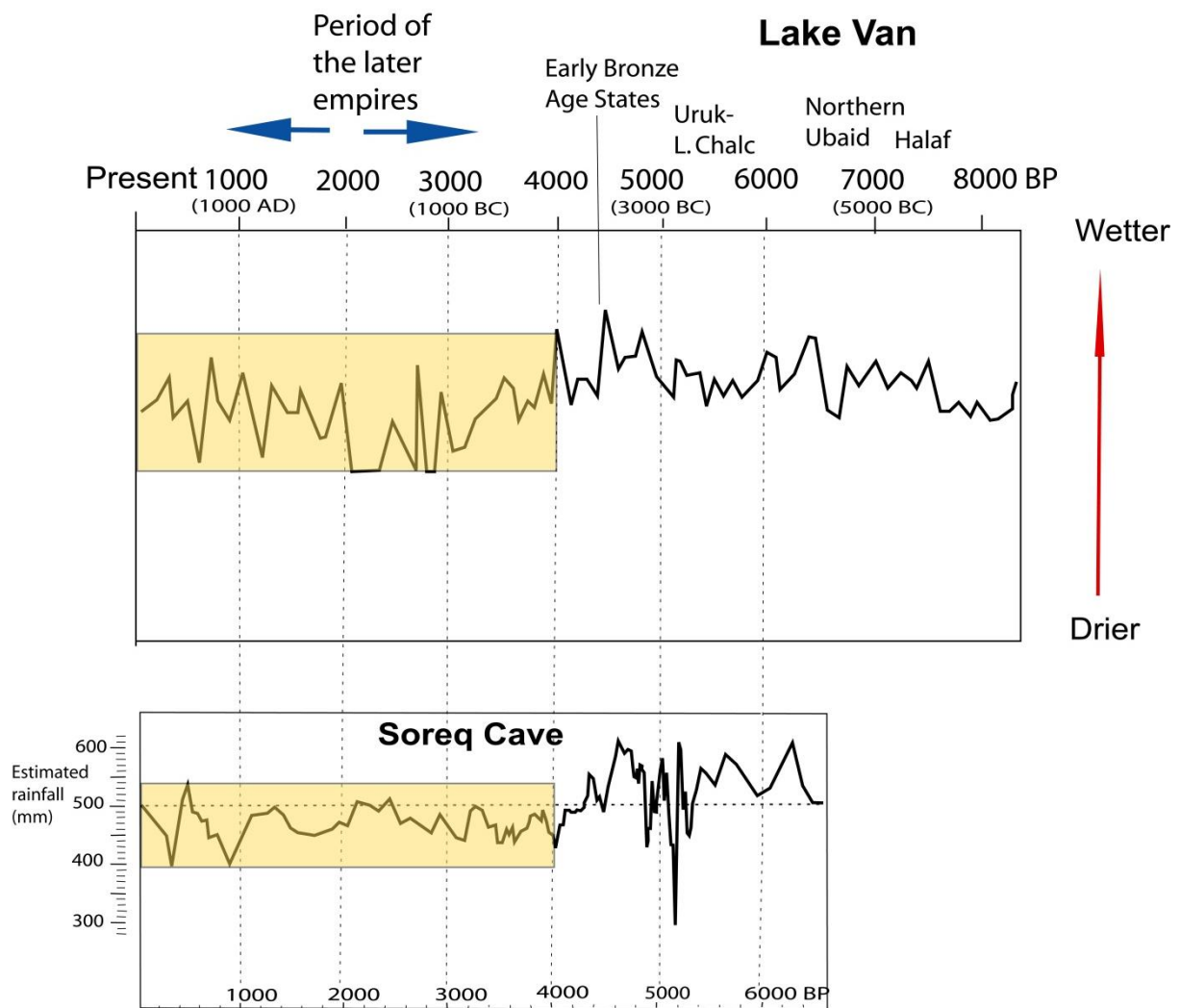


Fig. 5. Proxy climate curves from Lake Van (top) and Soreq Cave (below) based upon Oxygen isotopes (redrawn from Lemcke and Sturm (1997) and Bar Matthews and Ayalon (2004: Fig. 12). Note the drying trend after 4000 BP (ca. 2000 BC) indicated within the shaded box.

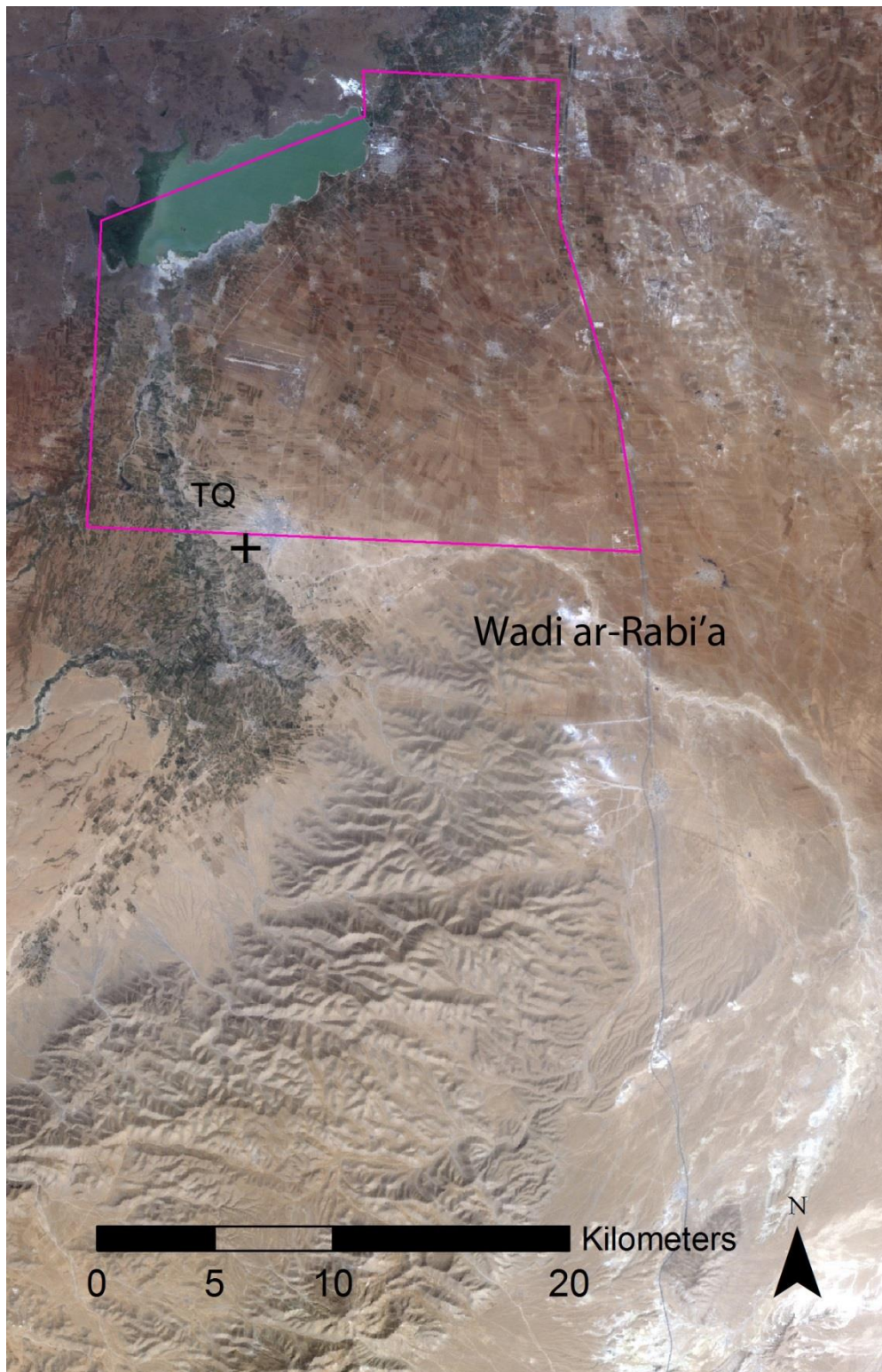


Fig. 6a. LANDSAT Thematic Mapper true colour image showing the course of the Wadi ar-Rabi'a – the bright linear feature crossing the centre of the image, and the ancient water mill of Tahounet el-Qantara, indicated as TQ. The pink box indicates the boundaries of the Southern Study Area of the survey, the black cross the location of the wadi section shown in

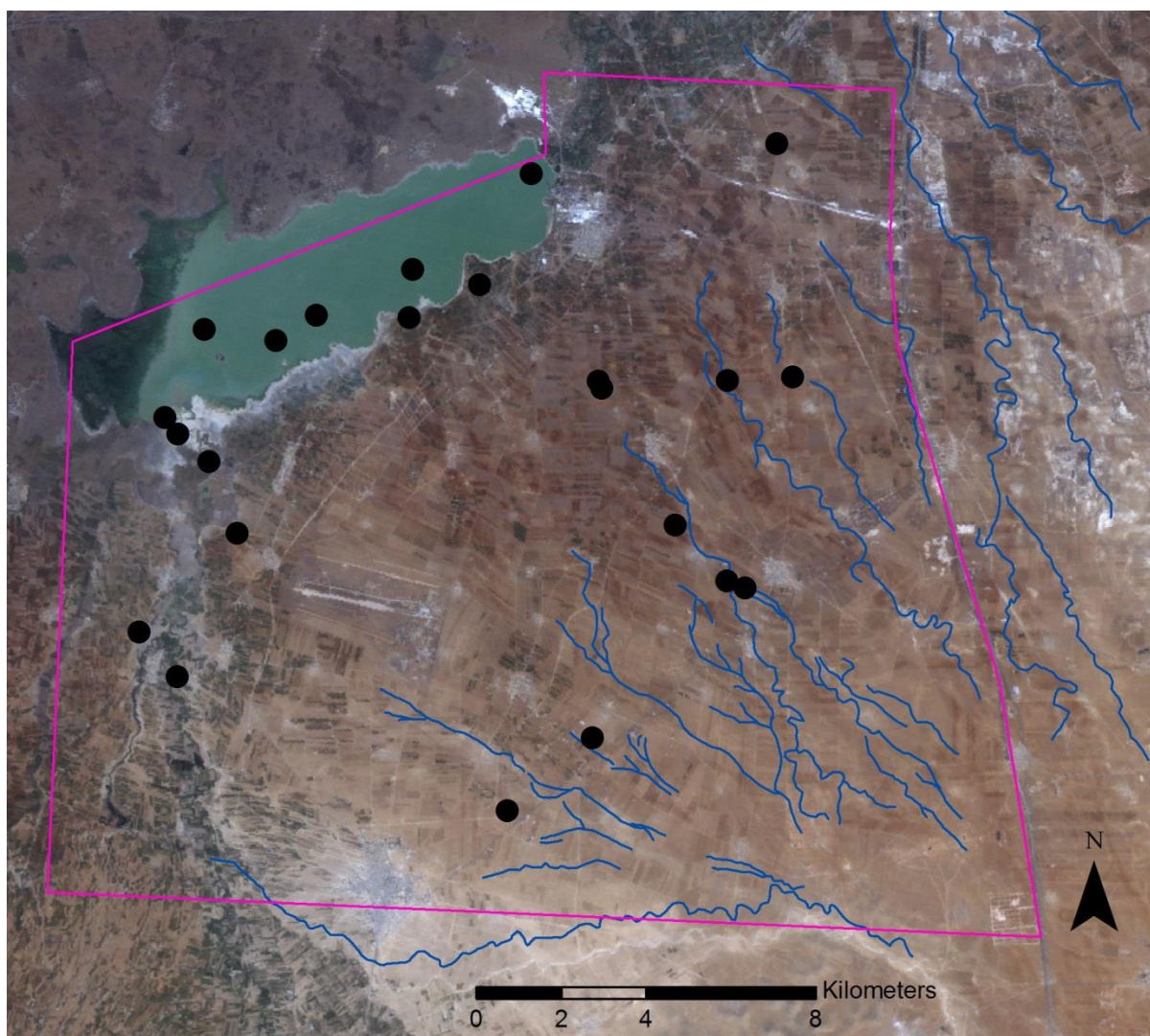


Fig. 6b Plot showing location of Bronze and Iron Age tell sites (black circles) and watercourses (dark blue) as evidenced by the presence of pebble beds identifiable in 1960s Corona imagery. Sites are located either close to the Orontes River (now partly under the modern lake) or along the seasonal watercourses.

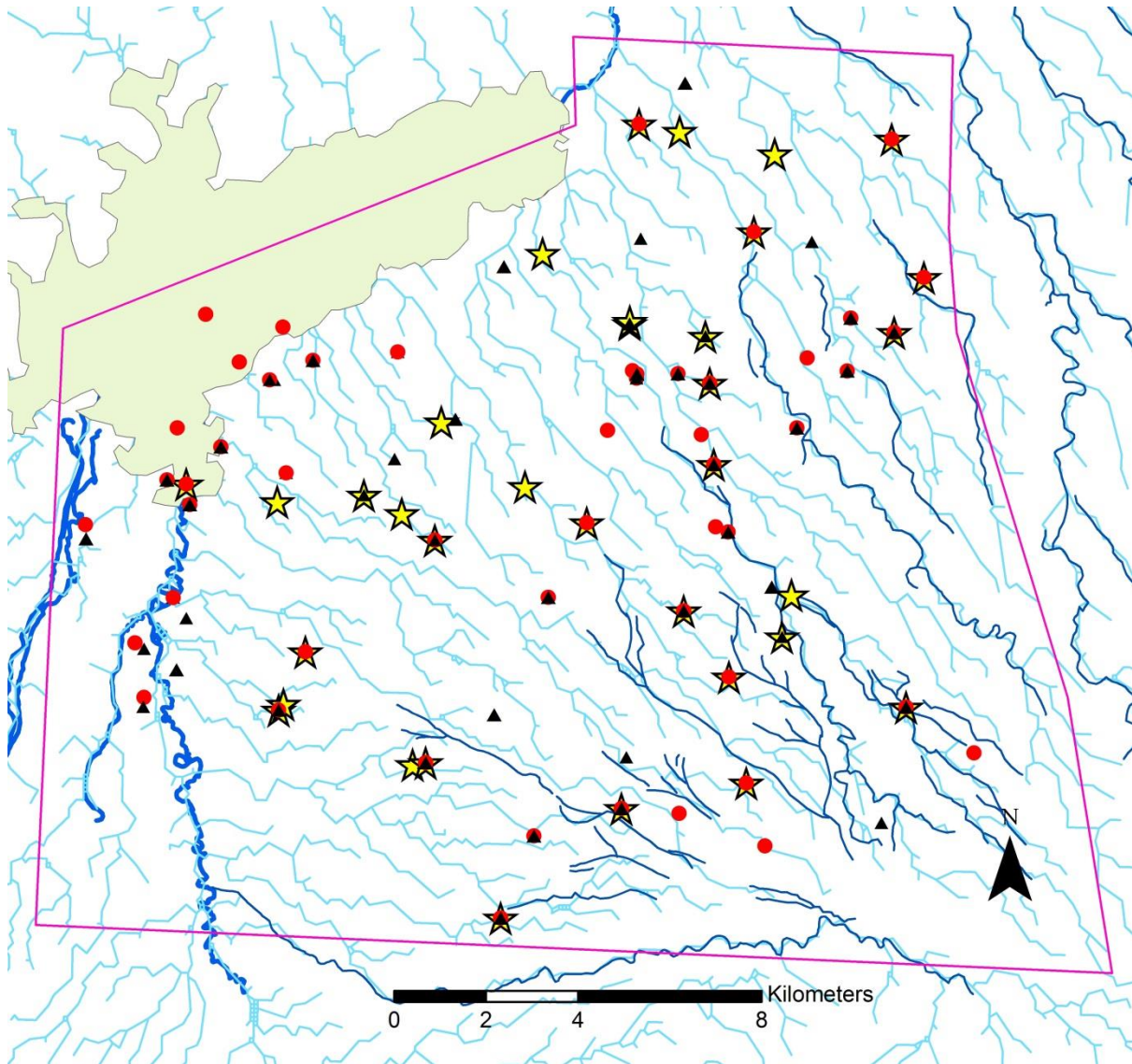


Fig. 6c Plot showing location of Roman and Islamic period sites (red dots) and the location of the surface depressions that we interpret as collapsing cisterns (yellow stars). Watercourses evidenced by the presence of pebble beds in 1960s Corona imagery are shown in dark blue while watercourses extracted from a predictive hydrology model using the SRTM DEM, appear in light blue. The association between the sites, depressions and watercourses, and the contrast with the Bronze settlement pattern in Fig. 6b is clear. The north-south course of the Orontes River is at the left of the image.

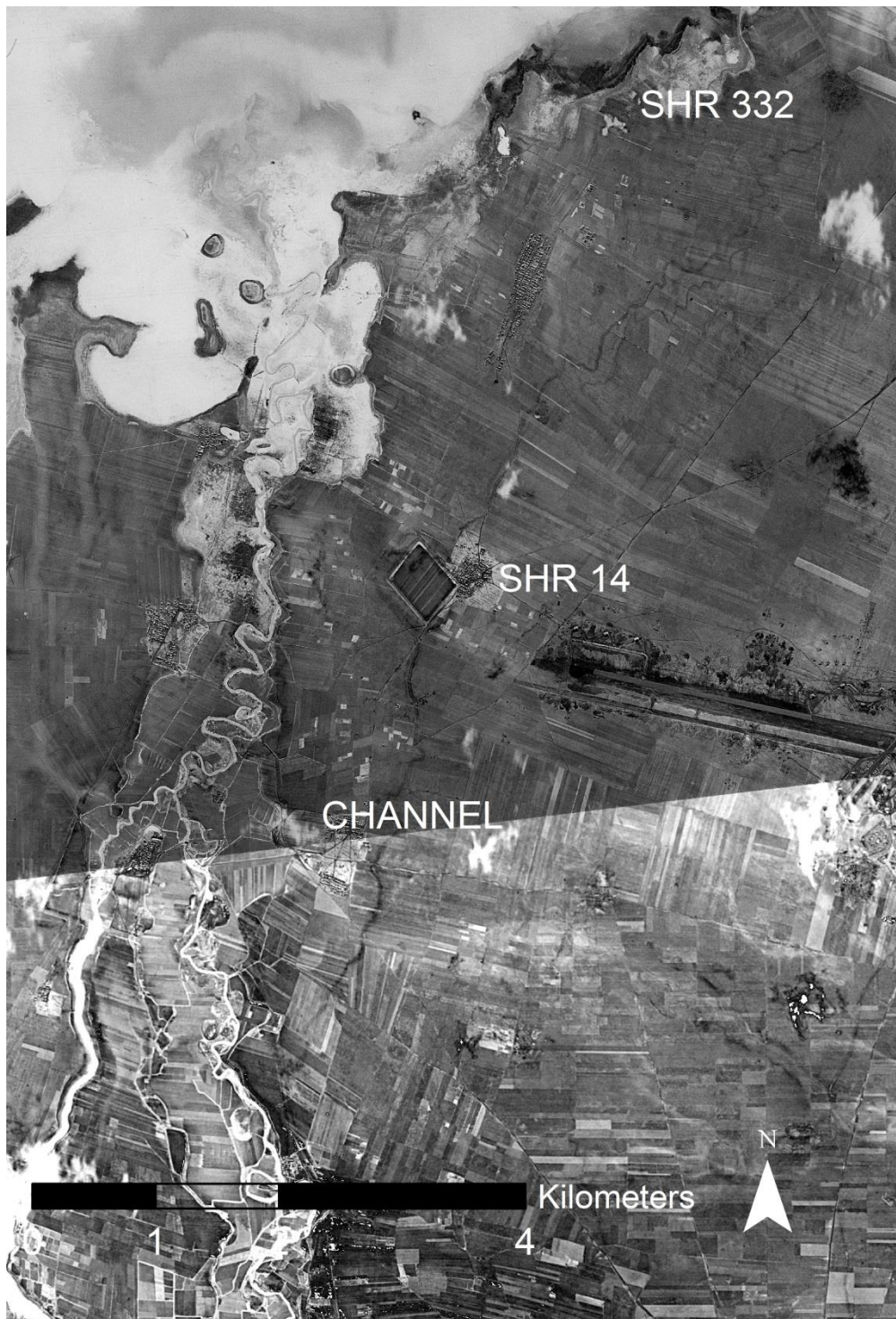


Fig. 7. Canal flowing from (close to) the Orontes River northwards towards large Roman site SHR 332. Note how the canal works its way around the Bronze Age ramparts of site SHR 14.

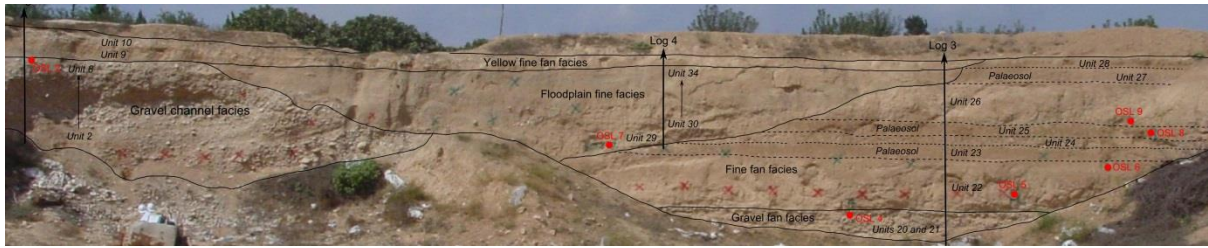


Fig. 8. Cross-section of the in-filled Wadi ar-Rabi'a south of al-Qusayr (see Fig. 1 for location), indicating Unit Numbers and location of OSL samples collected: not all of the latter have been processed.

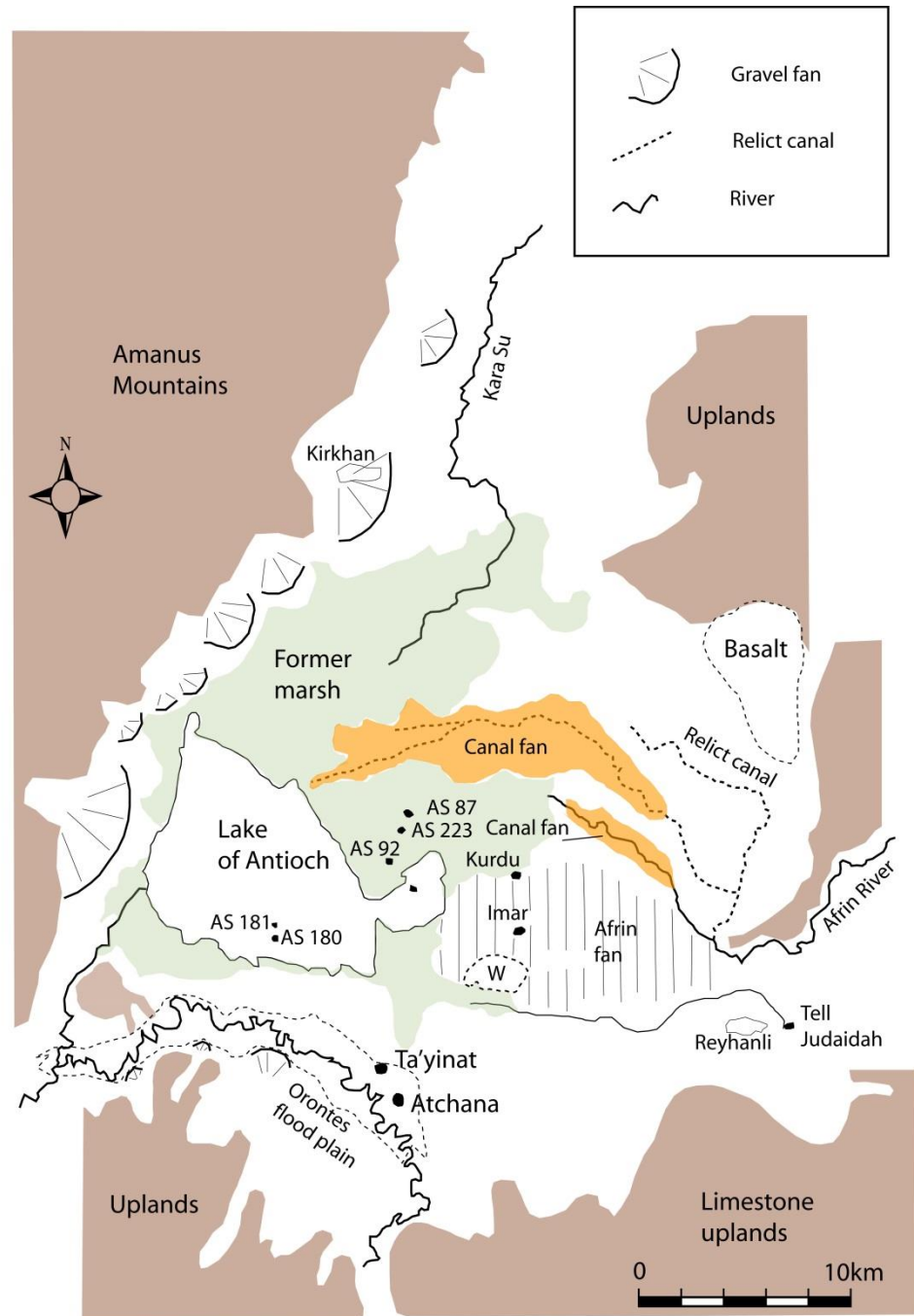


Fig. 9. Valley floor sedimentary environments and key sites in the Amuq Plain, southern Turkey. The surrounding uplands and mountains are indicated in dark grey, relict marshes surrounding the Lake of Antioch are in pale grey (together with sites that were flooded by the developing lakes and marsh. Note also the various Afrin canals that curve to the north and ultimately delivered excess water to the growing lake and marsh. W= sedimentary "window" of minimal sedimentation.

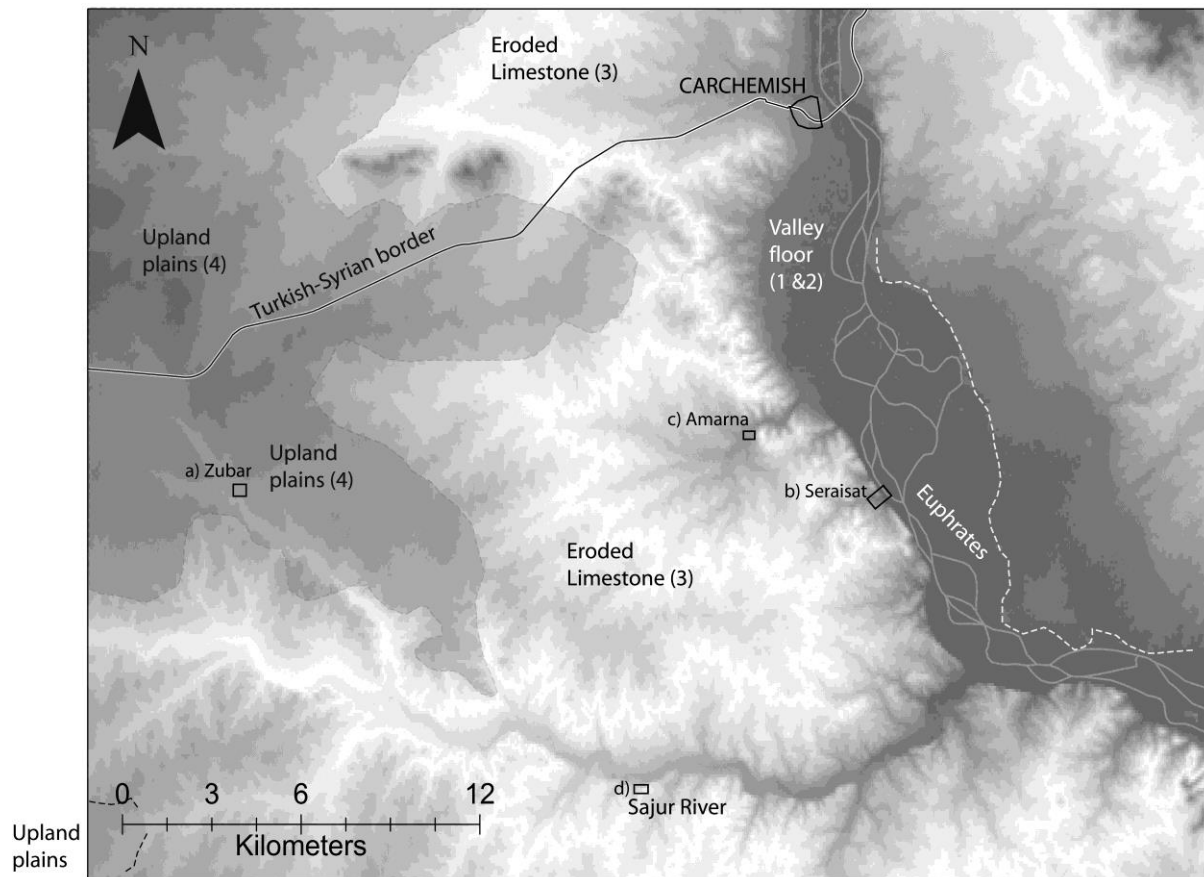


Fig. 10a. Relief map based on SRTM data of the Land of Carchemish survey area showing patterns of wadi erosion on the west bank of the Euphrates and the upland plateau further west. The discussed sections in the Nahr al-Amarna and the Wadi Seraisat are indicated at c) and b).

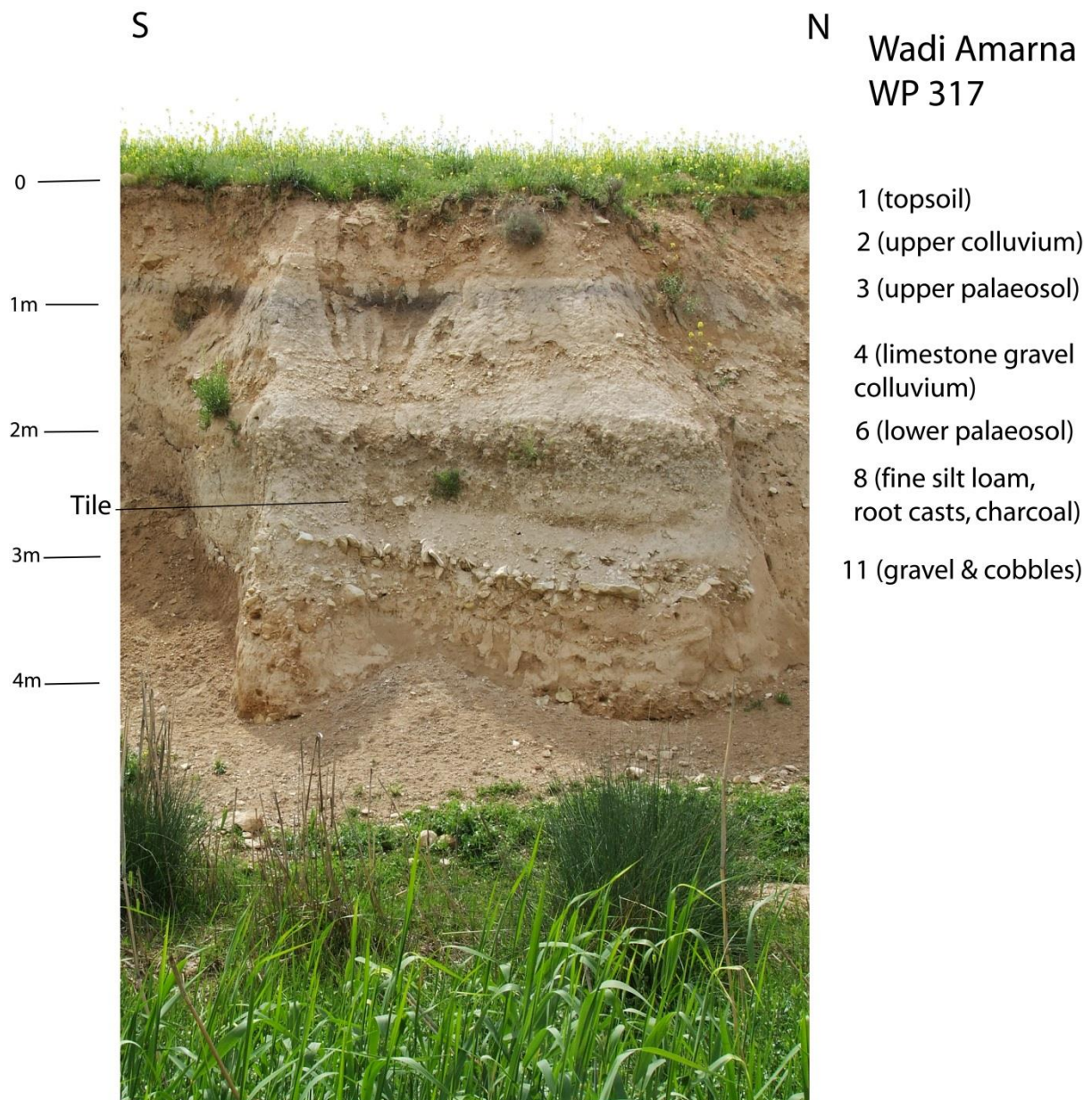


Fig. 10b. Section in the Nahr al-Amarna (WP 317). The tile at 3.5 m is of Late Roman-Byzantine date (3rd -7th centuries AD).

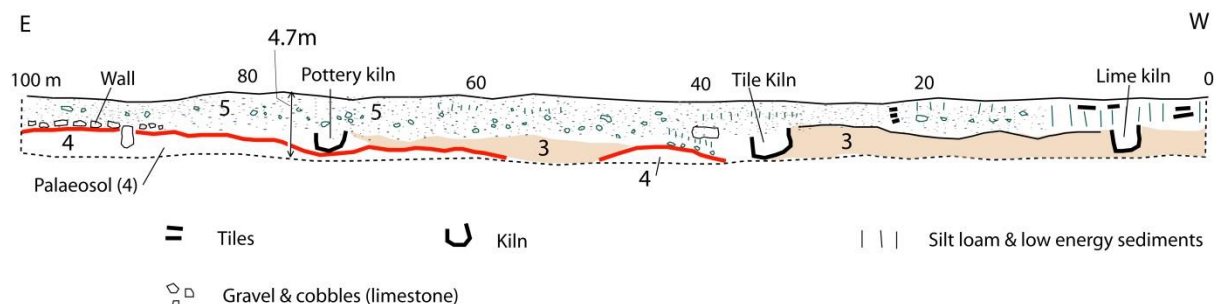


Fig. 10c. 100 m long sketch section through the deposits of the Wadi Seraisat near its junction with the Euphrates. Section depth at pottery kiln ca. 4.7 m. 3: Moderately-bedded medium-coarse limestone gravel in reddish matrix; the lime and tile kilns are cut into this. 4: Palaeosol: of brown silt loam, with calcium carbonate flecks and some cultural material. The upper part was interpreted as mixed by cultivation. 5: High-energy coarse gravel and cobbles

of limestone to 25 cm, in cream silt and sand matrix. Post-dates and overlies the kilns and wall.

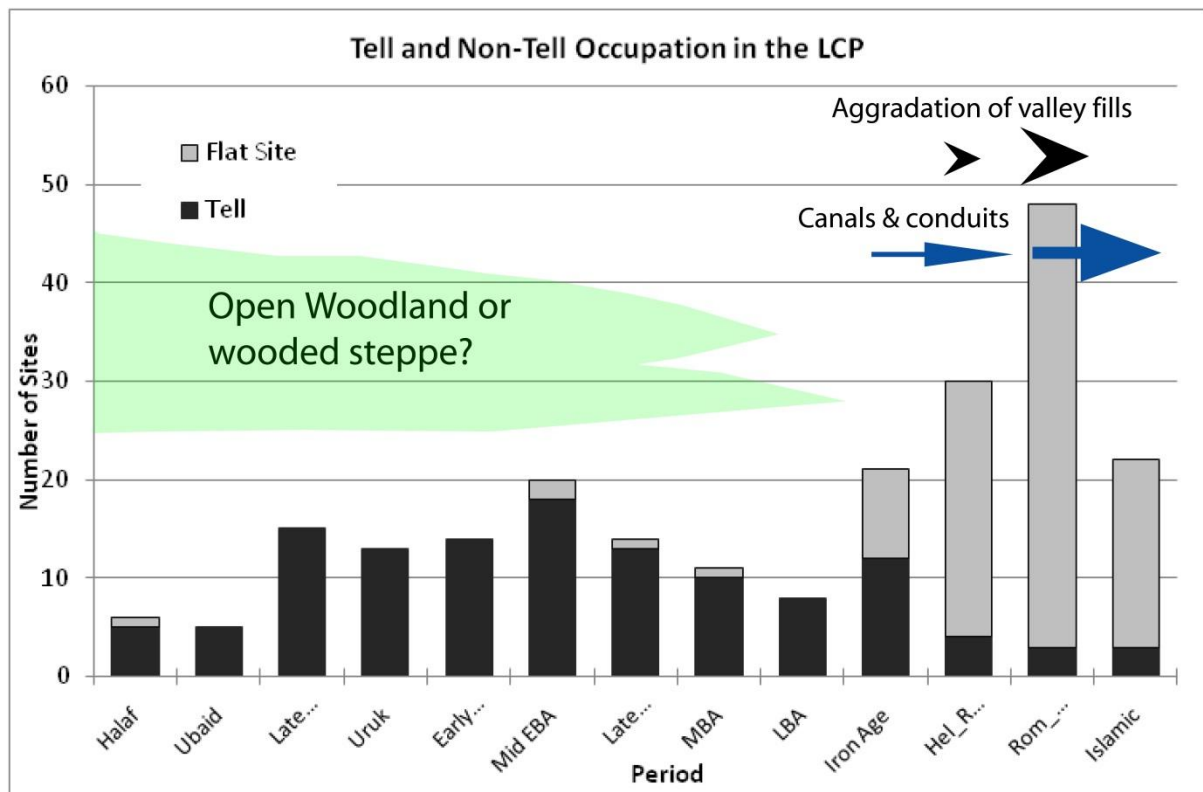


Fig. 11. Soil erosion phases in the land of Carchemish survey in relation to long term trends in settlement according to type of site, namely low or flat sites versus tells (settlement data compiled by Dan Lawrence, woodland data derived from Deckers and Pessin 2010, 2011).



Fig. 12. Valleys deeply incised into chalk-like limestone in the vicinity of Kurban Höyük in the Turkish Euphrates. According to a section exposed at KH 13, the erosional products from these valleys post-date the Early Bronze Age and probably accumulated in the Late Roman-Byzantine period. (CORONA image courtesy of USGS).

River Jaghjagh: 055

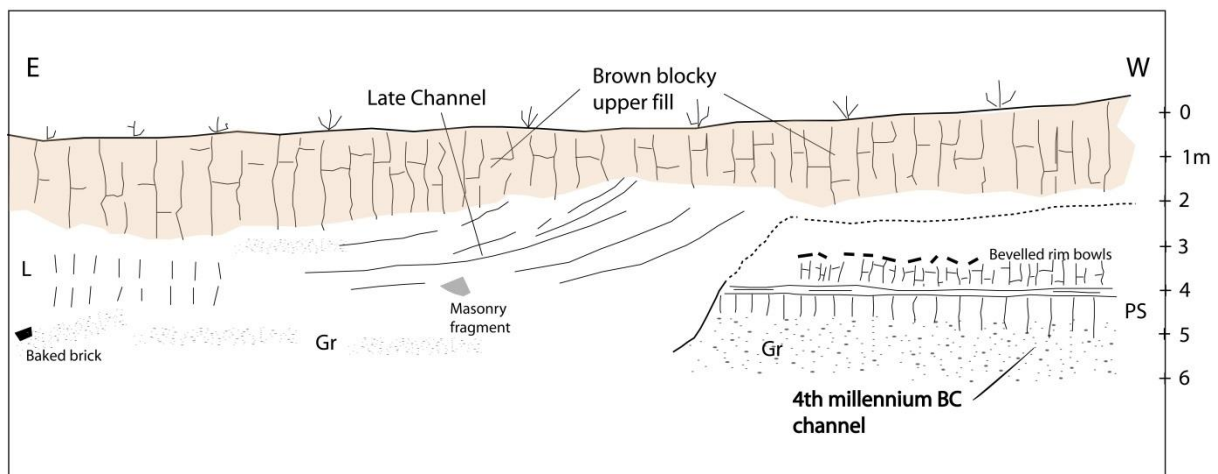


Fig. 13a. Section of riverbank at WP055 near Tell Barri, showing the fourth millennium BC river channel deposits and bank (to right), the latter with a scatter of Uruk bevelled rim bowls. The later channel (probably Late Antique in date) is to the left and the entire deposit sequence is overlaid by the upper brown blocky alluvium.

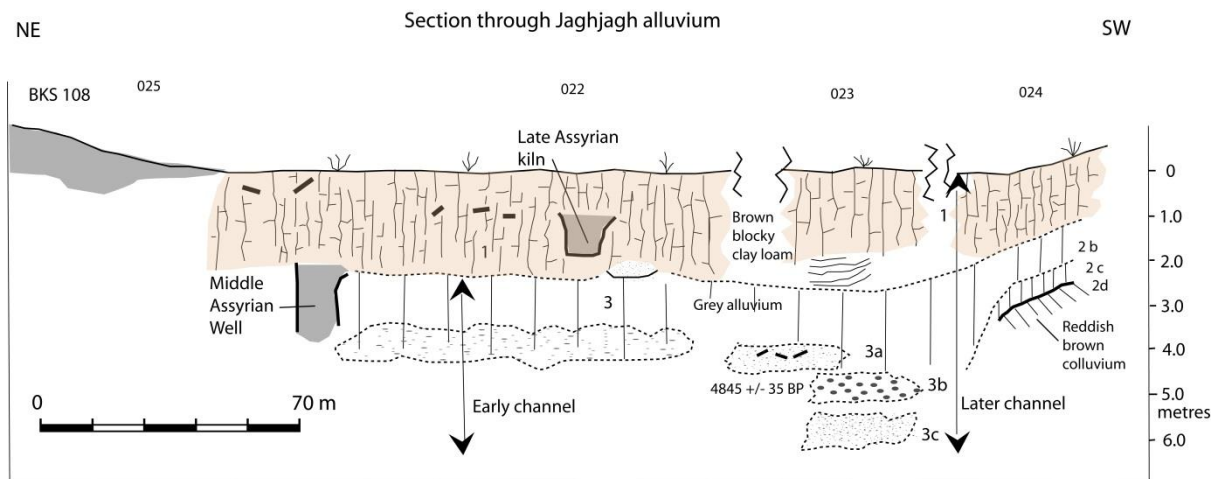


Fig. 13b. Section of riverbank near site BKS 108 showing the lower fills of the Chalcolithic channel (with C^{14} date of 4845 ± 35 BP from a mollusc shell). Note the presence of a Neo-Assyrian well (Iron Age) within the upper brown blocky alluvium and a Middle-Assyrian well (Late Bronze Age) immediately below).

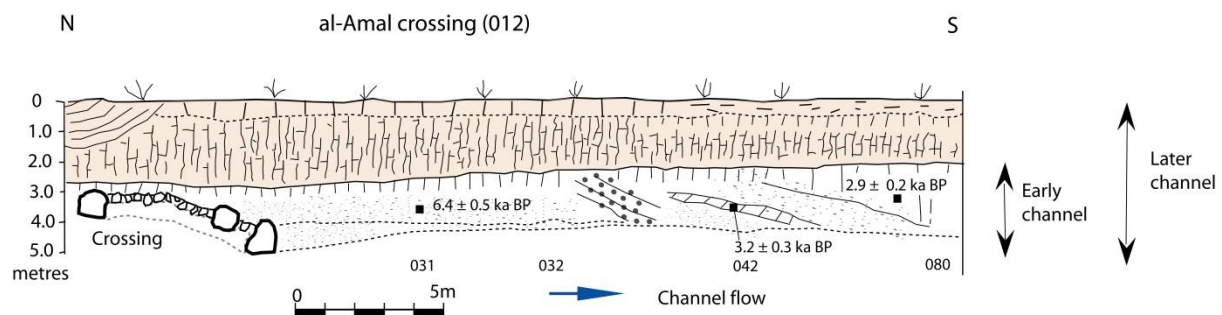


Fig. 13c. Section of River bank east of Tell Brak showing the stone feature known as the al-Amal crossing, together with the moderately high energy deposits of the early channel (at ca. 6.4, 3.2 and 2.9 K years BP), overlain by the brown blocky alluvium. For details of the OSL methods and results see Vandenberghe 2011



Fig. 14. Relict channel to north of Tell Hamidi in the Jaghjagh, in-filled with the upper brown blocky alluvium (Note this is HAM VII of Deckers 2011, fig. 4a).

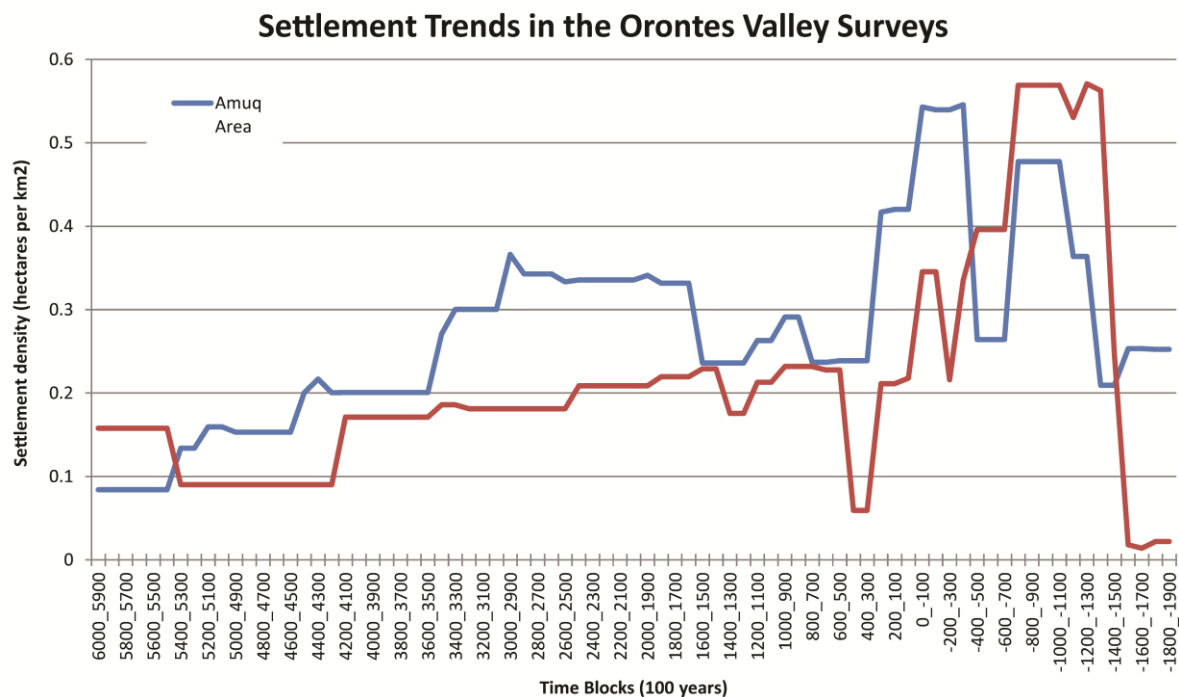


Fig. 15a: Aggregate settlement areas per km² for the western region of Syria and Turkey: Homs (SHR) and the Amuq Valley (AVRP).

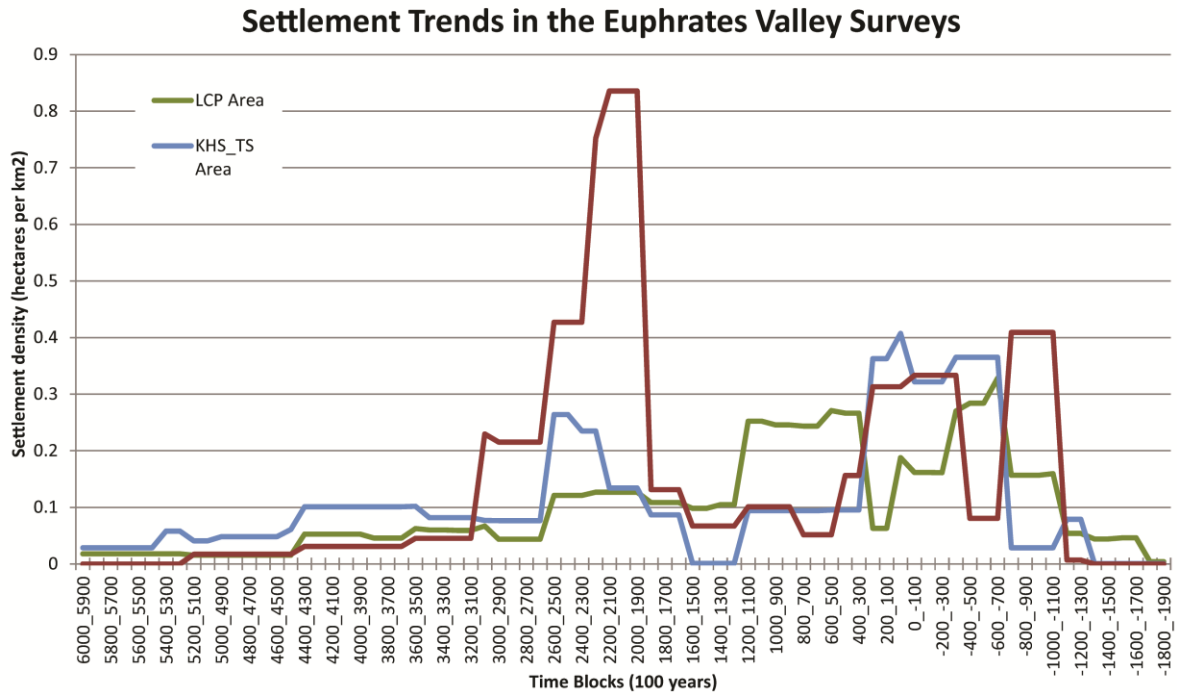


Fig. 15b: the same, but for the Middle Euphrates survey areas of the Land of Carchemish Project (LCP), the Kurban Höyük / Titriş Höyük surveys (KHS/TS) and the Tell Sweyhat Survey (SS) areas.

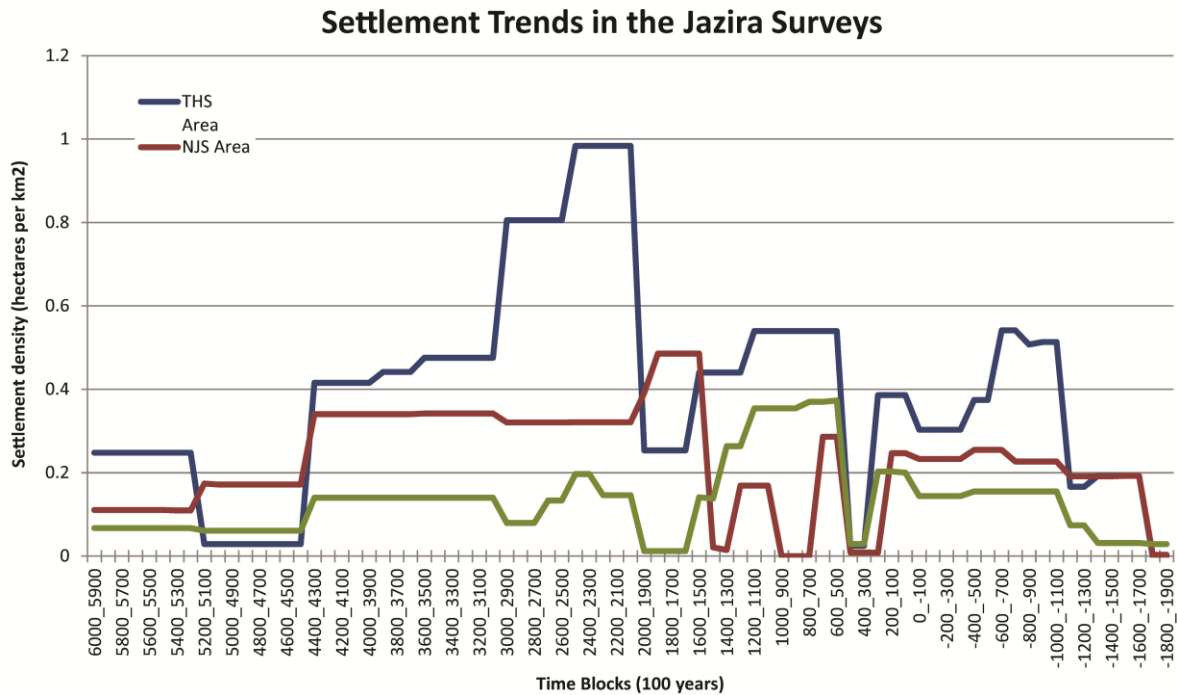


Fig. 15c: the same for the Jazira and Khabur regions in NE Syria showing settlement trends for the Tell Hamoukar (THS), North Jazira (NJS) and Tell Beydar (TBS) surveys.

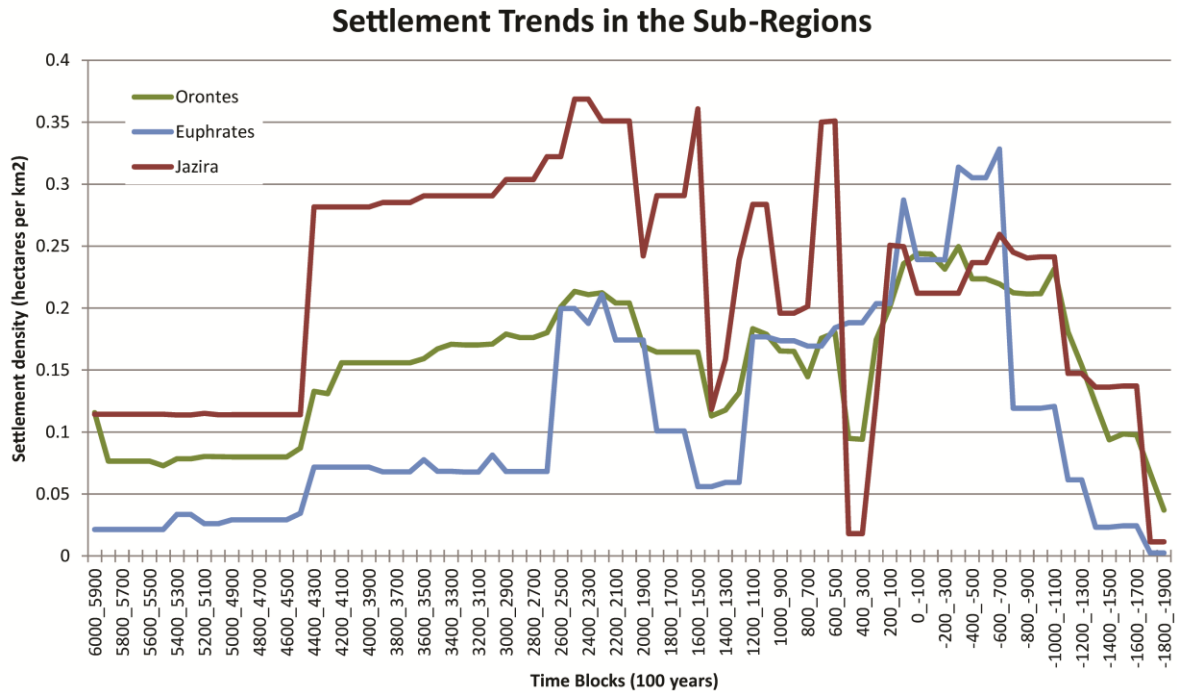


Fig. 16: The same survey data amalgamated for the west (Orontes), the Middle Euphrates and the Jazira sub-regions.

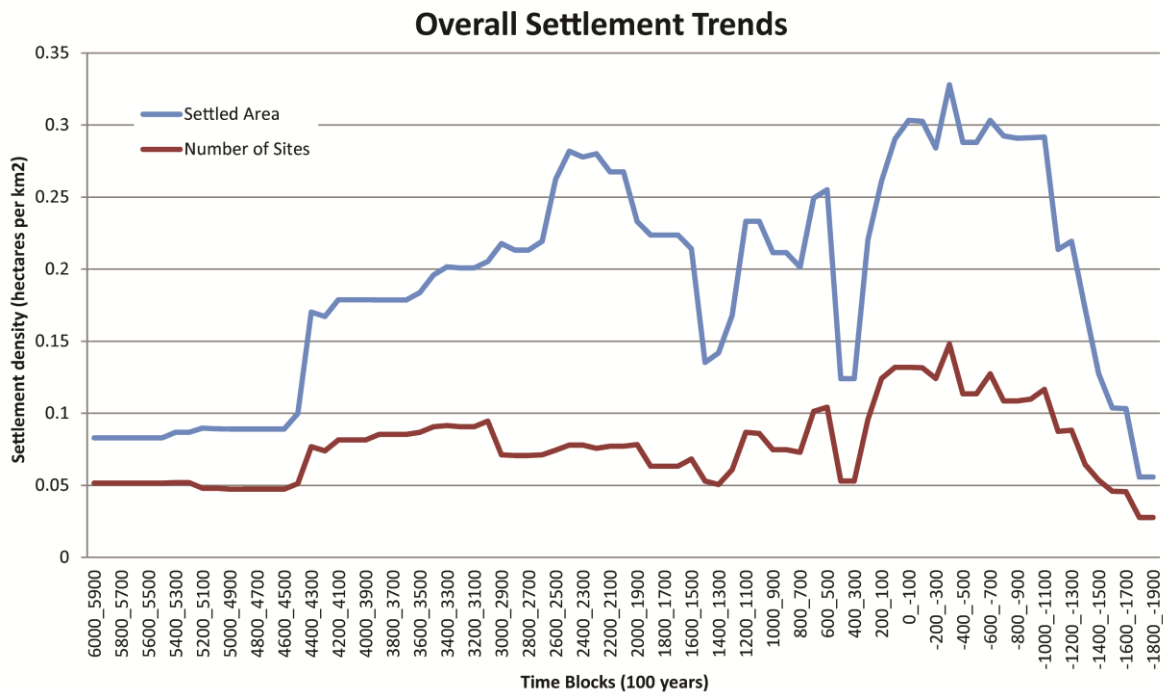


Fig. 17: Settlement trends amalgamated for all surveyed regions showing the long-term aggregate settlement per km² (top) and site counts per km² as discussed in text.

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